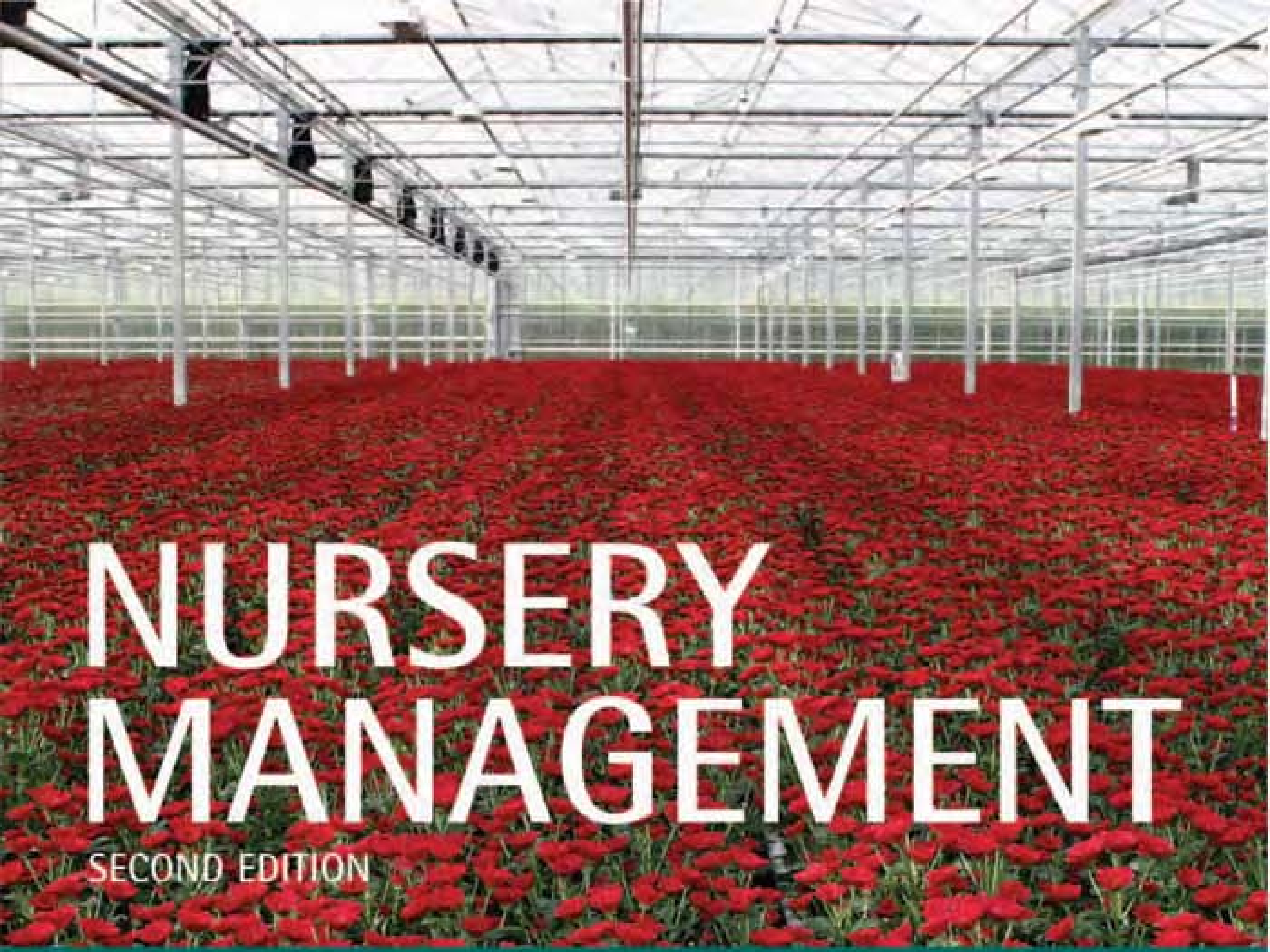

NURSERY MANAGEMENT

SECOND EDITION

   

JOHN MASON

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LAND LINKS

National Library of Australia Cataloguing-in-Publication entry

Mason, John, 1951– .
Nursery management.

2nd ed.
Includes index.
ISBN 0 643 09024 X (paperback).
ISBN 0 643 09213 7 (netLibrary eBook).

1. Nurseries (Horticulture) – Management. 2. Nurseries (Horticulture) – Australia – Management. I. Title.

635.9152068

Available from
Landlinks Press
150 Oxford Street (PO Box 1139)
Collingwood VIC 3066
Australia

Telephone:	+61 3 9662 7666
Local call:	1300 788 000 (Australia only)
Fax:	+61 3 9662 7555
Email:	publishing.sales@csiro.au
Web site:	www.landlinks.com

Cover
Main photo by istockphoto. Other photos courtesy of the author.
Set in Minion 10.5/13pt
Cover and text design by James Kelly
Typeset by J & M Typesetting
Printed in Australia by Ligare

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The author

John Mason graduated from Burnley Horticultural College, Australia, in 1971 with a Diploma in Horticultural Science. In the early 1970s and again in the early 1980s, he owned and operated small retail/wholesale nurseries. During the mid-1970s, he developed nurseries for two municipalities while working as their Parks Manager. Since 1979, he has been principal of the Australian Correspondence Schools, an international distance education college offering more than 140 different horticultural courses, and with students in more than fifty countries.

John has written hundreds of newspaper articles and more than thirty books, and has been editor and principal writer of four Australian magazines (including *Your Backyard* and *Garden Guide*).

He is an active member of both the Queensland Nursery Industry Association and the International Plant Propagators Society, and for five years was a national board member of the latter. He is a fellow of the Institute of Horticulture (UK) and Parks and Leisure.

Acknowledgments

Staff at Australian Correspondence Schools

Second edition

Naomi Christian
Mark James
David Mason
Peter Sherry
Alison Bundock
Adriana Fraser
Tim Stewart
Tosca Zraikat

First edition

Paul Plant
Vicki Bailey
Iain Harrison
Marguerite McQuade

Research and information

Elizabeth Cooling – nursery sprays
Brian Colling – barcodes
David Mason – computers
Horticultural Research and Development Corporation – market trends
Nursery Industry Association of Australia – market trends
Green Valley Plants, Hurstbridge Nursery, Tramstop Nursery, Atmosphere Retail Nursery – nursery trends
Dr Peter Bundock – plant breeding and biotechnology

Pictures

Leonie and John Mason

Drawings

Stephen Mason
Vicki Bailey
John Mason
Tosca Zraikat

Preface

Nursery Management is one of the few significant modern guides to managing a plant nursery and has been relied upon, worldwide, by nursery managers and students alike since its original publication in 1994. As author, I have received much-appreciated support, seeing it used as a text in horticulture courses in countries ranging from North America to Australia.

This new edition has been significantly expanded and updated, to be even more valuable to a broader range of readers. It brings together the knowledge and experience of qualified and experienced professional horticulturists from Victoria, New South Wales, Queensland and beyond. The book presents accessible and important information and guidance that will be useful to both production and retail plant nurseries, well into the future. Various chapters focus on the vital elements of nursery management, including site selection, selecting and managing nursery stock, the minutiae of everyday practicalities such as propagation, potting and transplanting, pest and disease management, and growing media, and the different types of equipment and structures required in a nursery. There is a discussion of the newly important areas of plant breeding and ownership rights, management skills and marketing, plus an extensive glossary, along with lists of seed and materials suppliers and professional organisations.

During 35 years of involvement in horticulture I have seen vast changes in the nursery industry worldwide. Developments in technology, globalisation and increasing sophistication in the marketplace have all made an impact, but many characteristics remain relatively unchanged. There is still a great deal of satisfaction involved in working with plants and, on the whole, a relatively relaxed atmosphere and character persist. One former high-flyer from the marketing industry recently said to me, ‘People working in horticulture are, on the whole, nice people; that isn’t the way in many other industries’.

To be successful in a modern nursery, you do need to be more than just ‘good with plants’ – business skills are vital and sometimes hard decisions are required, just like in all industries. However, for people who can develop the necessary management skills, managing a nursery may be a more relaxed and rewarding option than managing most other types of operations.

John Mason

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1

Introduction to the nursery industry

The nursery industry is literally a growing industry. It produces billions of plants every year, making major contributions to the forestry, vegetable, fruit, landscape, cut flower and parks industries. There will always be a demand for plants and, in turn, there will always be a need for nurseries.

Throughout the world, nurseries come in all types and sizes. Many are small family businesses, sometimes just a small hobby business to supplement the family's normal source of income. At the other end of the scale are large commercial enterprises that employ dozens of people and grow millions of plants. No matter what size, a nursery always needs good management if it is to be financially viable. This book aims to show how to make a difference to the financial viability, hence the success, of any nursery, irrespective of size or type.

The industry

The nursery industry has been a growth industry throughout developed countries for several decades, even during periods of general recession. Worldwide, there is a rapidly growing demand for potted plants: the US has the largest share of world consumption, followed by Germany, Italy and France. The main exporters of potted plants are the Netherlands, Denmark and Belgium (*The Nursery Papers*, No. 2001/1, NIAA, 2001).

The US is also the world's largest producer of nursery crops. According to the US Department of Agriculture, the nursery and greenhouse industry comprises the fastest-growing segment of US agriculture, with sales from those operations increasing by 43% between 1992 and 1997 ('About the Industry', ANLA website).

Similar trends are occurring in other centres of production. The UK gardening industry has reported good growth since the early 1990s (HTA website), and in Australia the nursery industry continues to expand, albeit more slowly than in previous years (*The*

Nursery Papers, No. 2004/1, NGIA, 2004). This is partly due to restrictions on the use of domestic water in a number of states.

The current surge of interest in gardening is influenced by a number of factors including increased home ownership, higher disposable incomes, an ageing population and changing life-styles. Media programs have fuelled interest in 'garden makeovers', resulting in the growth of landscaping services and consumer demand for instant colour, larger plants and more hard elements such as paving, outdoor furniture and water features. The demand for garden packages is a strong trend.

Figure 1.1: Many garden centres and large retail nurseries now carry furniture and associated outdoor products to satisfy customer demand.

Nurseries generally have been, and still are, small businesses employing fewer than five persons. There are good opportunities to establish new nurseries, provided they are selective in what they grow and that they maintain adequate standards in the quality of plants they produce.

It is important for nursery managers to be well-informed about industry trends, demands and conditions. Nurseries sell living things and, like all living things, plants are subject to the influences of abnormal weather, and plagues of diseases and pests. Plants are also subject to changing fashions. A promotion on television or in popular magazines often significantly changes the way the public spends, even if the change is only temporary. Averaged over a period of years, the demand for different types of plants may remain stable, but over shorter periods there can be very significant changes in the demand for one type of plant or another. It is essential to stay in tune with the marketplace and, wherever possible, predict changes in demand. Nurseries must maintain contact with the magazines, professional associations and gardening experts who can tell them what is to be promoted next, or what plants will be oversupplied or undersupplied in the near future.

Professional organisations

The nursery industry is well-represented by professional organisations dedicated to the interests of growers and retailers, and any newcomer to the industry is advised to become a member of a reputable association. Professional associations provide a wide range of opportunities including training and development, business improvement schemes, government lobbying and representation, and promotion and research.

The main professional body in Australia is the Nursery and Garden Industry Association of Australia (NGIA). In the UK the Horticultural Trades Association (HTA) includes around 1800 businesses representing garden retailers, growers, landscapers, producers and distributors of garden materials, and service providers. All the major UK ornamental plant growers are members of the HTA. The interests of US producers and retailers are represented by the American Nursery and Landscape Association (ANLA).

In addition to the national nursery organisations, there are many other professional organisations tailored to meet the needs of regional and special-interest groups, such as the International Plant Propagators Society (IPPS), landscape contractors associations and organic growers (see below).

Nursery accreditation

Nursery accreditation schemes are an important new development in both the production and retail sectors. The schemes operate in many countries, with the general aim of raising the status and professionalism of the nursery industry.

The programs differ in their technical focus and assessment procedures, but all are based on the concept of independent assessment to encourage business improvement. Depending on the scheme, guidelines and independent advice may be provided to promote best management practice. Assessment procedures generally involve external and internal reviews to measure such things as product quality, safety procedures, quality of facilities, staff knowledge and training, marketing and customer service.

Many nurseries involved in accreditation programs have reported benefits such as improved efficiency, better management, enhanced professional recognition and increased profits.

The two main accreditation programs in Australia are the Nursery Industry Accreditation Scheme (NIASA) and the Australian Garden Centre Accreditation Scheme (AGCAS). The Horticultural Trades Association in the UK has developed a number of certification schemes, providing quality standards accepted across the industry.

Organic certification

Certified organic production is increasingly used in the nursery industry because of the growing consumer demand for organic products. ‘Organic’ means different things to different people but, in order to be certified organic, a nursery must adhere to standards enforced by an organic certification body. Although this can impose restrictions on particular aspects of management, certification is a powerful tool for a nursery manager wanting to break into the ‘organic’ market because it indicates a definable standard of production.

Organic certification operates differently in different countries, but standards are generally enforced by government or private certification agencies, or a combination of both. In Australia the major certification bodies include Biological Farmers of Australia (BFA), the National Association of Sustainable Agriculture Australia (NASAA) and Organic Growers of Australia (OGA), all accredited by the Australian Quarantine and Inspection Service (AQIS). The major certifier in Japan is JAS, accredited by the Ministry for Agriculture Forestry and Fisheries Japan (MAFF). Organic agriculture in the UK is regulated by the UK Register of Organic Food Standards. Its largest certifier is the Soil Association. Organic certification in the US is regulated by the US Department of Agriculture (USDA). Quality Assurance International (QAI) is a private company that operates internationally from the US and is the world’s largest certification body. The International Federation of Organic Agriculture Movements (IFOAM) is an international umbrella body for the organic industry.

Organic nursery production focuses mainly on vegetables, herbs and fruit. Specific management changes may be necessary if you are considering a transition to organic production. Different standards may require certified organic seed, exclusion of synthetic fertilisers and biocides, and use of particular potting mixes. Some areas have established industries such as organic potting-mix producers, a factor which may facilitate success.

Types of nurseries

In the past, nurseries were involved in almost all aspects of the production and culture of plants. They grew a wide variety of plants and sold them both wholesale and retail, as well as supplying a wide range of allied products and services. Today all but the largest nurseries tend to specialise.

Organisational structure

Nurseries can be non-private (for example, run by government, community or conservation groups) or private businesses. Private nurseries can be individually owned partnerships (perhaps owned by a husband and wife or two friends), or corporate, such as a company, which has a legal identity of its own.

Nurseries can be classified in many different ways:

- according to what they grow, such as natives, exotics, seedlings, cottage garden plants, bonsai or bulbs;
- how they grow it, such as in-ground production or in containers;

Figure 1.2: This specialist nursery stocks bonsai and equipment for bonsai enthusiasts.

- the size of plants they produce, such as tubestock, small pots/containers, or advanced stock.

Nurseries which try to do everything rarely succeed. New nurseries should consider the following options carefully and define the scope of their operation to fit their resources, skills and knowledge. There are three main types of nurseries: production, growing-on and retail.

Production nurseries

Production nurseries, also known as propagation or wholesale nurseries, propagate plants and either sell them direct to retail outlets, landscapers and council parks departments, or wholesale them to growing-on nurseries. Success of production nurseries is affected by:

- innovation – supplying new varieties to the market or developing new ways of growing and presenting existing varieties allows the grower to develop new markets;
- specialisation – growing fewer lines in larger quantities allows the grower to improve efficiency;
- forecasting trends and meeting market demands – knowing what plants customers want, or are likely to want, and growing them in sufficient quantities allows the grower to meet consumers' requirements and thus maintain customer loyalty.

Figure 1.3: A large production or wholesale nursery.

Growing-on nurseries

Growing-on nurseries buy bulk quantities of seedlings or small plants from propagators. At the time of purchase, the plants are growing in plugs, trays or tubes; the plants are then potted into larger containers and grown on for a period of time, adding value to the nursery's original purchase.

In addition to increasing plant size, specialised growing techniques, such as topiary, may be used to add value to the plant during the growing-on phase.

The most critical aspect of production in growing-on nurseries is developing a quality product for the retail market. At the time of resale, every plant must be at its peak, displaying healthy, vigorous and sturdy growth. The plant must presented appropriately, in a clean and attractive pot, with fresh potting mix (no weeds or residues on the surface) and appropriate support (small stake or trellis) if necessary. Labels must also be supplied (but not attached).

Retail nurseries

Retail nurseries buy plants from production/propagation nurseries and resell them at a profit. 'Greenlife' (the industry term used to distinguish plants from other nursery products) sold by the retail sector include seedlings, bulbs, containerised and bare-rooted plants and trees. In addition, garden centres sell associated products such as dry goods (pots, packaged potting mixes, fertilisers, sprays) and bulk landscaping materials.

There is an increasing emphasis on the supply of 'lifestyle products and services' in retail outlets, such as outdoor furniture, gift lines, display gardens, cafés and landscaping services.

What to grow

It has often been said that the downfall of a nursery manager is to be 'too much of a plant collector and not enough of a businessperson'. Most people who work with plants love plants, and it is very easy to be tempted and grow the types of plants which you love most. This is often the nursery manager's Achille's heel. It is essential to be very careful when choosing what to grow – it is pointless growing lots of plants if there is no demand for them.

Some plant varieties require more space than others. Sprawling climbers or groundcovers can take up a lot of room; tall slender trees can take less. Slow-growing plants don't have to be sold as soon as they are good enough for sale, but fast-growing plants deteriorate fast so must be sold quickly, unless you have the resources to continually keep potting them into larger containers.

Some of the main plant choices are:

- trees and shrubs – climbers, conifers, deciduous plants, groundcovers, fruit trees and vines, native trees and shrubs, exotic trees and shrubs;
- bedding plants – annual flower and vegetable seedlings;
- potted colour;
- foliage plants – indoor foliage and flowering plants, hanging baskets, palms and ferns;
- herbs;
- perennials and cottage plants;
- bulbs and tubers;
- water plants;
- bonsai.

You may choose to have a general nursery, growing or selling a wide range of plant types; or choose a theme, such as bonsai or cottage gardens; or choose to concentrate on a specific type or variety of plant, such as carnations, fuchsias, roses or geraniums.

How to grow

Plants can be grown in the ground or in containers. Plants grown in the ground are dug up when they are to be sold, or transplanted and grown-on in containers before being sold. Plants grown in containers may be sold in the same containers or may be potted-up prior to sale. Container growing uses mainly imported soil mixes (growing media). In-ground growing can take more space, might require a little more labour in some respects than container growing, and does require the nursery to be sited on suitable soil.

Figure 1.4: In-ground production is particularly suited to deciduous plants that undergo a dormant phase.

Table 1.1: Comparison of container versus in-ground nursery production

Container-grown	In-ground
Plants can be transported and sold in their containers, with little disturbance to the plant	Plants must be lifted from the ground and packaged in a way that minimises damage to the plant
Containers can be readily moved if necessary during production	In-ground stock is difficult to move during production
Soil/growing media for plants must be brought (imported) into the nursery	Plants are generally lifted and sold bare-rooted; soil remains and can be re-used/cultivated
Soils/growing media are readily sterilised in small batches to reduce pest and disease problems	Harder to control pest and disease problems
Rootstocks are harder to quickly bud or graft	Easier to bud/graft rootstocks in-ground as the rootstock will not move too much during grafting as the roots secure the plant
Plants have root balls restricted by size and shape of container	Plants grown in-ground have greater opportunities for root zone development
Careful watering is critical due to the restricted/limited amounts of growing media for plants' roots	Watering is less critical due to greater opportunities for root zone development and lower water from soil

Nursery standards

A nursery must set and adhere to certain standards if it is going to operate profitably. These standards can be broken down into three main groups: cost-efficiency, quality and size.

Cost-efficiency

Cost of production

There must be a sound relationship between production cost and sales price. Both monetary figures must be constantly monitored and maintained at an acceptable level to ensure the business remains profitable. It is important to remember that a good nursery manager must not only be capable of producing and/or maintaining good-quality plants and allied products, they must also be able to sell them profitably.

Cost of Production + Profit = Sales Price

If the cost of production becomes too high, profit will decrease. In such a situation the sales price must be increased, otherwise the profit figure can become a negative amount (i.e. the nursery might be losing money rather than making it). In order to control cost-effectiveness, a manager must understand and control all the factors which influence the cost of production. They may also need to adjust the sales price figure in order to maintain an acceptable profit.

Cost of production is influenced by the following factors:

- cost of site – lease/rent value or purchase costs;
- cost of site services – power, gas, water etc.;
- cost of materials – soil, pots, fertilisers etc.;
- cost of unsold plants – a certain proportion of stock may be lost, may die, or may just become unsaleable. Some nurseries budget as much as 30% of stock being thrown away;

- labour costs – including your own time as well as employee hours, holiday pay, superannuation requirements, health cover etc.;
- advertising/promotion – printing, advertising in magazines etc.;
- selling costs – transportation, invoicing etc.;
- taxation – payroll tax, income tax etc.

Profit
This figure should be over and above money which you earn as wages. If you are only working for wages (with no profit), then it would be better to put your money into a different form of investment and work for someone else. Profit should be greater than the interest rate which you could get by investing your money elsewhere. Profit should normally be at least 15–20%. If the nursery is small, the profit margin per plant should be larger. If the nursery is large, the profit per plant can be kept lower. In that situation profit comes through quantity of sales.

Sales price
The figure for which a plant is sold can vary considerably. Retail price is normally about twice the wholesale price. This being the case, the wholesaler must sell in large numbers in order to maintain profitability. Wholesale price varies considerably. Generally speaking, the figure is largely affected by:

- the reliability of the nursery supply. If the wholesaler is well-established and known to be a reliable source of plants, they can demand a higher price.
- the quality of plants offered. Higher prices are paid for top-quality stock.

Quality standards

Some factors affecting quality are:

- general plant health. Does the plant show evidence of pest or disease damage, dead leaves, burned leaves, markings on stems, lack of vigour?
- hardness or softness of plant tissue. Has the plant been hardened off, or will it be susceptible to fertiliser burn, frost, wind or sun?
- uniformity. Is plant presentation consistent? Plants of a particular variety should be in the same size and colour pot, with the same type of label. The plants should be of similar shape and size.
- labelling. Are plants correctly and clearly labelled? Picture labels are preferable to printed labels without a picture. Tie-on labels may be preferred to stick-in (soil) labels because they cannot be removed easily and put with a different plant. Stick-in labels are, however, generally quicker to place in position than tie-on labels. Hand-written labels do not generally

Figure 1.5: Clear labels are essential for nursery stock, and customers favour picture labels.

provide as much information as commercially printed ones and the writing often fades or runs, making them hard to read.

Size standards

Some countries, including the US, have established standards for the sale of nursery stock, including container sizes. In other countries the system is less formal, but there are unwritten standards which are generally adhered to. Plants presented in the wrong type of container are usually more difficult to sell. For example, containerised plants are generally grown in rigid plastic pots. Plastic bags are less expensive and some growers use them for growing-on in production nurseries to keep costs down, but they are rarely used for selling plants in retail nurseries.

Certain types of plants are generally sold in certain size pots. Most trees and shrubs for the home garden are sold in 150 mm (6") or 200 mm (8") pots. Herbs and indoor plants are usually sold in smaller plastic pots (75 or 100 mm, 3" or 4"). Seedling vegetables and flowers are sold in plastic punnets. Advanced plants are sold in 10 L (2 gallon) plastic buckets. Seedling-grown plants for use as farm trees or for large-scale revegetation are often sold in 50 mm (2") tubes. Deciduous trees and roses are sold bare-rooted over winter.

Starting out as a nursery producer

New nurseries, like many other small businesses, often fail because they haven't been properly planned. Nurseries can be started with minimal cash investment, but the size of the operation must be geared to the amount of cash invested. If the initial investment is small, then the nursery should be small and grow slowly. Even if a sizeable investment is made initially, it is wise to retain up to one-third of the available cash to carry the business for the first couple of years. Nursery profits can fluctuate greatly from year to year. If the first year is a bad season because of pests, diseases, bad weather or poor sales, a reserve of cash may be necessary to carry the nursery through to the second year.

A manager new to the nursery industry is usually limited by lack of skills, poor knowledge of the market and small reserves of money available to develop the operation. It is possible to start a profitable part-time nursery in the backyard. This type of operation will supplement a normal income, and at the same time allow the industry newcomer to learn from experience. A serious business venture is quite different: you don't have the time to learn by making mistakes!

New nurserypersons should avoid growing the more difficult plants, which often require more time and sophisticated equipment. This means that they are more expensive to deal with. Plants which require a longer time to grow to a saleable size should also be avoided until the nursery is generating enough sales to provide a sufficient income to keep it profitable while the plants are growing.

New nurserypersons are advised to produce plants in the standard packaging (e.g. 150 mm/ 6" plastic pots). The product will usually be saleable in this packaging!

They are also advised to start with high-demand plants. Low shrubs, groundcovers and potted or instant colour are generally in higher demand in urban areas than are large shrubs and trees. The highest demand for large shrubs and trees is in the rural community. A plant with a flower on it is almost always more saleable.

Figure 1.6: The ability to diversify and stock a variety of products that are in demand is a key factor in the success of new nurseries.

Revamping an existing nursery

There is always room for improvement, even in the best-run nursery. A good nursery manager will keep an open mind, continually review the way things are done in the nursery industry and look for better, more up-to-date and more profitable ways of doing things. They should continually perform the following tasks:

- look for better prices for materials, e.g. pots, labels, stakes and potting media;
- reduce the numbers grown of some plants and increase the numbers of others in response to changes in consumer demand;
- upgrade equipment;
- train staff;
- refine propagation methods for each plant variety that they grow;
- analyse the success of marketing, e.g. compile statistics on the response to promotions, the sales achieved from month to month etc.;
- calculate and analyse the profit and adjust prices accordingly;
- attend industry seminars and keep in touch with current research, trends and developments in the industry;
- use the internet as a research tool and join professional associations involved in industry development.

If you are not doing these things, maybe you should start.

Figure 1.7: Properly trained staff and good customer service are essential to the success of new nurseries.

Organisation is the key

You can increase profitability a great deal by simply organising and planning what you do in a nursery. Planning should be an ongoing process, not something you start and finish, then forget about once a nursery has commenced operations. There are basic questions which you should ask yourself over and over; you should constantly review what your nursery is producing or selling, how you are producing or obtaining those products, and how you market your products. When planning, consider how to achieve the following goals.

Reduce wasted time

Keep asking yourself: 'Can I get the same work done in less time if I do things differently?' In some cases, mechanisation of tasks may save considerable time and labour. In other cases, simply rearranging the placement of propagating and potting-up benches will speed the flow of plants and materials into and out of propagation areas.

Reduce wasted facilities and equipment

Keep asking yourself: 'Can I do the same work just as well (or nearly as well) without the expense of that extra equipment?' You should buy extra equipment only if it will lead to extra profit. It's a trap to buy equipment because everyone else does, without giving serious consideration to how it will affect your profitability. It can be more cost-effective to hire some types of equipment, particularly equipment that, while necessary to the nursery's operation, is used infrequently. When planning on hiring equipment, however, make sure it will be available when you require it.

Reduce wasted materials

Be self-critical. It is easy for expenses to increase because potting mix gets spilt on the floor; because you buy too many labels and pots which can degrade or break down over time, or get damaged if stored incorrectly; or because you fertilise or spray more often than necessary. You should predetermine what you need and buy that quantity, with perhaps a little extra in case of losses due to accidents or sudden extra demand for products. It is a mistake to just keep buying materials when you need them, without having first calculated what your requirements should have been. Remember: money spent on excess materials that sit there doing nothing except taking up valuable space is a waste of an asset that can be readily used elsewhere and more profitably in the nursery's operation.

Make the most efficient use of labour

This is particularly important if you are employing staff, but it also applies to getting the most from your own labour. It is important to plan which tasks each worker will be undertaking the next day, week, or even further ahead. Thus both staff and employers know what has to be done rather than wasting time trying to sort out what they are supposed to be doing, missing tasks or duplicating performance of tasks. It is also important to have suitably trained and the right mix of staff. There is little point in having, for example, staff busily propagating plants, if you don't have the support staff available to care for the plants once propagated, or to do the marketing and transporting.

Assessing opportunities

If you decide that growing or selling plants is for you, and you are ready to consider opportunities, use the following questions to help you assess the likelihood of success for each different opportunity.

- Is there a market in my community for this kind of business? Will people buy my product or service, and are there enough buyers to sustain the business in this area?
- How much money would it take to start the nursery? Will I be able to borrow that much money? How much will it cost me in the long run?
- How many hours a week is it likely to take to run the nursery? Am I willing to commit that much time?
- What are the particular risks associated with this nursery? What is the rate of business failure? Why have similar businesses failed, and how can I overcome these risks?
- Does my background prepare me to run this kind of nursery? Do most people who own this kind of nursery have more or different experience or knowledge than I do? What do I need to learn, and am I willing or able to learn it quickly?
- How much money could I make running this business? What is my lowest likely net profit? Is this sufficient to meet my needs, and when can I expect to make this?

Launching a new business, introducing a product or service and buying advertising are so expensive that misjudgments can mean disaster for an entrepreneur. Market research can avoid costly errors by telling you what people want to buy, and how they want it presented to them.

Regardless of how great you think your product/service is, it is virtually impossible to sell any product or service that people do not want. On the other hand, it is very easy to sell people something they do want. That is the whole point of market research: to find out what people want so you can provide it for them. To be successful, a business owner must know the business's market, its customers and potential customers, and how they perceive the business's products and services.

Market research is the way to obtain, analyse and interpret the information necessary for making marketing decisions. It provides the timely information you need to:

- reduce your risks;
- identify and profit from opportunities;

- improve existing products;
- plan and refine advertising campaigns;
- spot problems and potential problems;
- evaluate alternatives.

Fortunately, market research does not have to be expensive. Although large corporations often spend millions of dollars on market research, an entrepreneur can accomplish much for very little money. Initially you need to determine such things as whether there is a market for your product or service, how that market can be reached, who your competitors are, the current condition of your industry or field and its future outlook.

Key market research questions

Who will buy your products and/or services?
Customers are the most important element of any business. Successful marketing depends on reaching customers most efficiently. This is best done by targeting your market carefully. Target-marketing means using your marketing resources more like a rifle than a shotgun, going after only the customers most likely to want your product or service. The more clearly you identify your potential customers, the more likely your efforts are to be successful.

What do they want?
When entrepreneurs say that 'everyone' is a potential customer for their product, it usually means they have not really targeted their market. This can lead to wasting huge amounts of money on inappropriate and ineffective marketing. The more you know about who you are trying to reach, the more efficiently you'll be able to market to them. In addition to knowing who your customers are, you'll need to know how many of them there are, where they are, what their wants and needs are, and what will attract them.

Trends in the retail nursery industry

Market research

This information on market research was funded by the Horticultural Research and Development Corporation and the Nursery Industry Association of Australia, March 1991. It is also based on customer surveys (1407 residents surveyed nationally, Sept./Oct. 1990):

- types of specialised gardens: 28% native bush garden;
- major influences when choosing plants or garden accessories: 30% from newspaper/magazine (compared to 35% from television garden program, 15% from nursery staff);
- awareness of retail nursery advertising and promotion: 44% any advertising remembered; 31% letterbox catalogues; 25% garden shows;
- main positive attitudes about plant purchasing: 88% say staff knowledge is essential; 83% want to help the environment; 72% desire quality;

- consumer needs from nurseries: 52% want knowledgeable staff; 46% want good service.

This information comes from the perception of nursery retailers (202 nationally) about demand increase or decrease:

- bedding plants: 70% increase, 9% decrease, 21% static;
- potted colour: 67% increase, 9% decrease, 24% static;
- herbs: 61% increase, 8% decrease, 31% static;
- perennials: 58% increase, 10% decrease, 32% static;
- trees/shrubs: 52% increase, 9% decrease, 39% static;
- citrus trees: 50% increase, 6% decrease, 44% static.

Satisfaction with plant or product quality supplied by wholesalers:

- 59% satisfied;
- 15% neither;
- 25% dissatisfied.

1991 survey by the Australian Horticultural Correspondence School

In 1991 the Australian Horticultural Correspondence School surveyed its Australian students. Students were given a selection of different types of plants and asked which they grow in their own gardens. Responses were as follows:

- vegetables 83%;
- indoor plants 82%;
- fruit trees 80%;
- natives 80%;
- annual flowers 71%;
- herbs 66%;
- lawn 66%;
- perennials 59%;
- azaleas 48%;
- orchids 23%;
- water plants 12.5%;
- bonsai 5%.

2004 survey by the Australian Correspondence Schools

A survey of retail and wholesale nurseries in Australia in 2004 was carried out by the Australian Correspondence Schools. All nurseries surveyed had been operating for a minimum of 4.5 years. The survey determined the following interesting points:

- all nurseries surveyed employed some form of horticultural consultant. One-third of respondents employed an accountant;
- the most popular form of marketing was the use of signs and posters. The second most popular form of marketing was distribution of catalogues. Other forms of marketing included advertising in magazines, stands at trade shows, and media;

- the average profit margin nurseries worked to was 70%. For example, if a plant cost a nursery $1 to produce, including all wages, materials and other costs, the plant would be sold for approximately $1.70;
- most nurseries had several main plants that provided the majority of their income;
- nurseries were asked what they perceived to be the most common reason for nursery businesses failing. 85% of nurseries surveyed stated that poorly trained staff could cause the business to fail. Other common reasons included poor presentation of plants and the nursery site, weekend-market plant sellers undercutting prices, high overheads and an inability to diversify and sell products other than plants despite demands for them.

2

The nursery site

The location, size and internal characteristics of a nursery site must be appropriate for the type of nursery you are operating.

Area of the nursery site

The amount of land required for successful operation can vary from 0.1 ha (0.25 acre) up to hundreds of hectares. The amount of land you acquire may depend on the following:

- cost of land – you may have to compromise your ideals with what you can afford;
- availability of land – you may be unable to get the exact size you want. For example, although you need only a 1 ha (2.5 acre) lot, land might be selling only in 2 ha (5 acre) lots in your preferred locality;
- spacing and size of plants – consider the final pot size prior to sale and the space required between plants;
- the proposed output of plants – you will need to estimate the maximum numbers of plants in the nursery at any one time;
- space required for buildings, storage areas, roads, paths, carparks, dams and waste management facilities.

There are viable commercial nurseries operating out of backyards with as little as 400 sq m (4300 sq ft) of space devoted to plants. Some of these backyard businesses generate enough income to support a family, but good management is particularly critical for businesses where space is at a premium. Many of the largest nurseries started out as small backyard operations.

Propagation nurseries and tissue culture operations generally require less space because the plants don't take up much room and don't need to be kept and grown-on for long before being sold. There are a large number of plants produced compared to space

Figure 2.1: The amount of land available will vary depending on the location and size of the nursery operation. The cost of land can be one of the largest investments for a new nursery operation.

used in these nurseries, and a high income per unit area. Nurseries which deal with very valuable collectors' plants (such as rare plants, bonsai, carnivorous plants and orchids) may also require less space than other nurseries because they can generate more money per plant.

Retail nurseries can vary in size from a small shop in a suburban shopping centre up to a large regional garden centre that may be 5+ ha (12.5+ acres) in size. Retail nurseries with fast turnover of plants need less space because they don't need room to hold or store plants for lengthy periods between sales.

Advanced plant nurseries generally require considerable space as plants can be grown for years in containers or in-ground before being sold. Nurseries that grow grafted plants or advanced trees in field rows will require at least 1 ha (2.5 acres) of land to be a viable operation.

Planning restrictions

Various government authorities have control over the way land can be used. Planning departments in both local and state governments can stop a nursery from being operated in some locations and under some conditions. The worst nightmare for any businessperson is to have a profitable business closed or be forced to restrict its operations because the necessary permits weren't obtained at the outset.

Before you start up or buy any nursery, you should check that it is located in an area where a nursery is allowed to operate. If buying, your purchase contract should state 'subject to appropriate planning permits' or an equivalent phrase, depending on the country you live in. Some local government organisations zone areas of land and only allow certain activities to be carried out in each area. For example, in residential areas it may be illegal to operate a nursery business. Always check with your local government authority that your intended land use is acceptable in the area.

Nursery site and location

Nursery site characteristics

Slope
Sloping sites will require earthworks for buildings and terracing for areas to place plants. Earthworks can be expensive and you may require the services of an engineer and permits from your local government authority.

Drainage
Speak with neighbours about drainage in the area and consider all parts of the property.

Flooding
Is the site prone to flooding? Many councils and local government organisations will allow you to search their records to determine whether the site is flood-prone.

Bushfires
Find out whether the site is in a high fire-risk area. If it is, your local government authority may ask you to prepare a bushfire management plan.

Access
Can you get onto the site easily and is it easy to move around the site? If you are planning to have customers and service people visit the nursery, consider the type of access they will need. Is there enough parking for your anticipated number of customers?

Existing facilities
Are buildings and infrastructure already present? How much will you need to invest to improve the site's facilities enough to operate a nursery?

Microclimates
Trees provide shade, and frost or sun protection, but can restrict light and reduce growth rates. This is an advantage with some plants, and a disadvantage with other plants.

Factors affecting location

The location of a nursery is determined primarily by the following factors.

Proximity to markets
Retail nurseries and garden centres rely on direct sales to customers so they are best sited in close proximity to a town or housing subdivision with a reasonable size population. Market proximity is not so important for specialist and wholesale nurseries. Specialist retail nurseries usually sell a sizeable proportion of their plants through mail order; the remainder are sold to customers who are generally more willing to drive long distances to buy their plants.

Large production nurseries are usually located on the outskirts of towns and cities where land is considerably less expensive; in fact some of the largest wholesale nurseries are hundreds of kilometres from cities, where large tracts of flat, inexpensive land and good access to water and other services offset the costs of transportation to city markets. However, the cost of transporting stock to market must be considered.

Cost of land

The cost of land is one of the most important factors to consider in deciding the location and size of the nursery. Naturally, land costs vary. Prime horticultural land and land close to large population centres is more expensive than outlying, less-productive land.

Access to services

If services such as water, power and phone must be brought some distance to your property, this can be expensive. The closer you are to these services, the cheaper the services will be.

Soils

Soil type and quality may be important, especially if extensive earthworks are required. Foundations of structures may become expensive if the soil is very sandy or contains a large proportion of expandable clay. If you plan to grow plants in the soil as stock plants or in-ground production, you will need fertile, deep, well-drained soil to obtain the best results. It may be useful to have the soil tested by a laboratory prior to purchase.

Climate

Consider rainfall, temperature, frost, hail and wind. These factors can vary even over the space of a few kilometres. Speak to the weather bureau, and local residents, to obtain detailed information.

Operating costs can be reduced by selecting plants suited to the climate. This is especially important for large production nurseries, where heating, cooling/lighting systems, spray programs and irrigation can be significant expenses. For example, if you plan to propagate large numbers of roses, establish the nursery in a cool to mild, dry and sunny climate optimally suited to rose production. Otherwise, much time and expense will be spent battling the many diseases and pests that flourish in moister climates.

Aspect

In the Southern Hemisphere, sites facing north receive more sun and can bring plants into flower a little earlier than south-facing sites. Alternatively, southern slopes may be the best site for a nursery growing cool-climate plants. The converse applies in the Northern Hemisphere.

Isolation from diseases

This is an advantage if the nursery is growing plants which have particular disease or pest problems. For example, some areas have disease-free ratings for certain diseases. This provides an instant advantage over competitors who are growing stock in areas that are not declared disease-free. Nursery hygiene is important to prevent disease entry into the nursery.

Air quality

Consideration should be given to nearby industrial businesses. Pollutants can contaminate the air and deposit residue on nursery stock. If there is a pungent smell in the air, prospective customers may be disinclined to visit your business. Chemicals drifting from adjoining properties (e.g. farmers using aerial spraying) may also affect nursery plants.

Water

Nurseries use lots of water, so water availability and quality are very important. Connection to the mains is usually a guarantee of a reliable supply of clean water, but the costs can be considerable. You should also remember that nurseries are not always exempt from water restrictions during extended dry periods, in which case the cost of buying water can be astronomical.

Water from on-site bores and dams are options for rural nurseries, but supply and quality can be a problem. Chemicals in the water may result in toxic symptoms or slow death of plants. The conductivity of the water must be measured to indicate its salt concentrates. The higher the conductivity, the less suitable the water is for plant culture. Irrigation water from dams or bores may leave residues on the foliage. In the short term, algal residues from dam water do not affect plant growth but they will deter customers from buying the plants. In the long term, algal residues can reduce photosynthesis and impair plant growth.

Labour supply

If you plan to establish your nursery away from a populated district you may have difficulty in hiring staff willing to travel or with adequate horticultural experience.

Security

Security is essential to prevent damage by both animals and people. Native and domestic animals can diminish nursery production by eating stock plants, damaging irrigation systems, and knocking over and breaking plants. Theft and vandalism are also common problems in untended nurseries. Security measures include high fences, strong gates and hired security patrols. A staff member living on-site will also deter intruders.

Government regulations

All regulations, compliances and statutory requirements must be considered. Each city or shire will have slightly different regulations with regard to building codes, hygiene practices, occupational health and safety, operation hours, signs etc.

Nursery design

Key elements of nursery design are landscaping, drainage, facilities and production areas.

Landscaping

Landscaping contributes enormously to the nursery atmosphere. It is also a useful way of advertising the nursery’s plants, so it is well worth expending some effort in this direction. The carpark and the sales areas are both excellent areas for display beds that attract customer attention.

Drainage network

Surface water from rain and overhead sprinklers should be immediately removed from exposed surfaces. Customers and employees may slip and injure themselves on wet surfaces, leading to insurance problems. If the nursery is a retail venture, customers will not want to walk through water to get a plant. Puddles of water also provide breeding grounds for diseases and many insects. A network of drainage channels will help prevent these problems. Good drainage is an integral part of the nursery site.

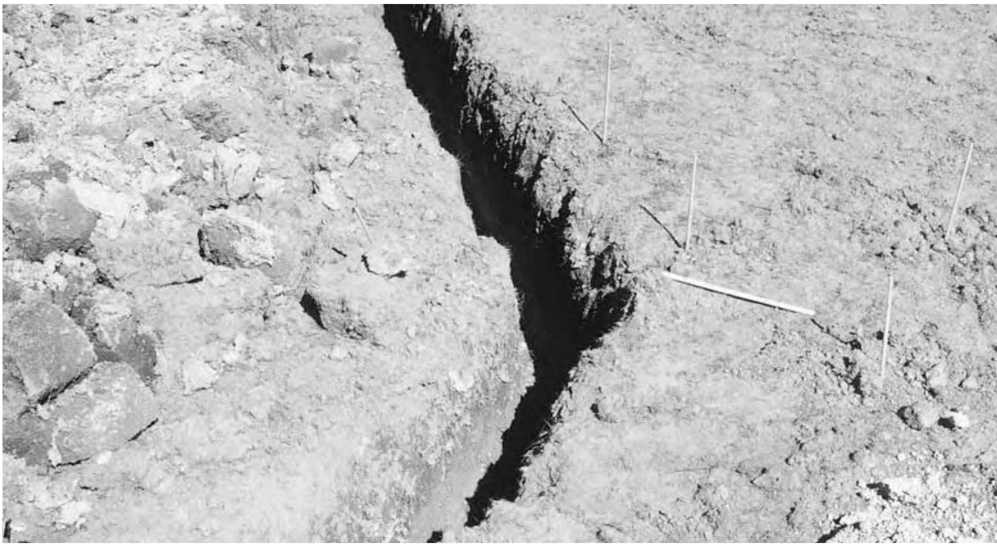

Figure 2.2: Prior to setting up a nursery, site drainage should be assessed and any problems dealt with. Poor drainage can lead to disease outbreaks and an unsafe working area.

Facilities

Administrative offices
These are often located in a central position to give control over production, sales, and receiving and dispatching of stock.

Circulation and parking
Convenient access and parking is especially critical in retail nurseries. Carparks for the public should be well-marked, with clear signposts, and preferably covered with hard surfacing material such as asphalt. Avoid creating sharp bends in driveway areas.

Receiving and dispatch areas will need sufficient room for large trucks to turn around. Elevated docks and assembly areas for stock should also be considered for ease of loading/unloading.

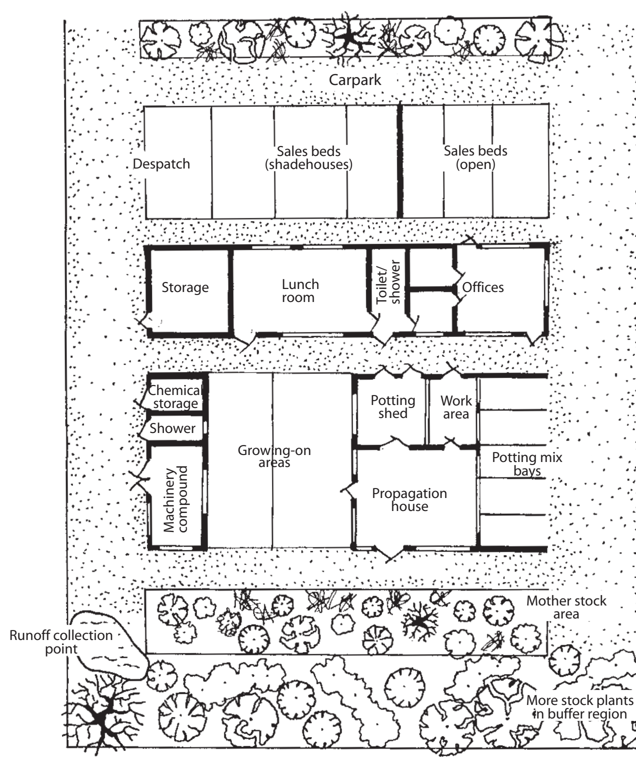

Figure 2.3: Layout of a wholesale nursery, selling general container plants.

You will also need to consider provision of vehicular access to storage and sales areas within the nursery, for shifting large quantities of plants or moving heavy advanced plants.

Employee facilities
Parking facilities, lunchrooms, supervisors' offices, toilet blocks and so on for nursery employees must be considered at the planning stage. Clean, neat facilities will help maintain employee morale. It is best to keep staff facilities separate from the public areas of the nursery.

Public areas
Minimum facilities for the public in a retail nursery are the sales area, display gardens and toilets. However, these days many customers expect a lot more when they visit a nursery. Many of the most successful retail nurseries and garden centres now sell more than just plants and associated plant products such as fertilisers, potting mixes and pots. When customers visit a nursery, they have the opportunity to browse and shop for a wide range of products, unwind over coffee and cake, wander through inspirational display gardens, and watch over children playing in a safe environment. Providing leisure facilities for customers gives both short- and long-term benefits. The nursery is more likely to attract a wide range of visitors, customers will stay longer in the nursery and spend more money, and they are more likely to come back and repeat the experience.

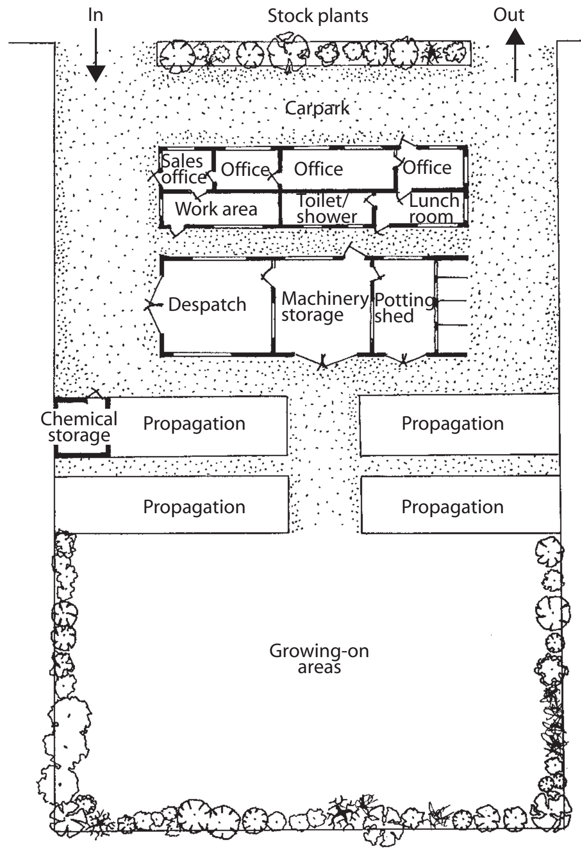

Figure 2.4: Layout of a wholesale propagation and tubestock nursery.

The design of public areas should be both functional and aesthetic. They should be designed so that they can be maintained at the highest standard at all times; for example, paths and walkways should be covered with cement or blue metal so they can easily be kept free of rubbish and weeds.

Facilities for the public include:

- outdoor sales area – provide good signage, wide smooth paths, plants set on benches at eye height, plant trolleys and covered walkways;
- indoor sales area – must be spacious enough to accommodate customers queueing at the cash registers as well as being a display and storage area for a range of goods, including giftware, indoor plants, seeds, fertilisers, pesticides and other sales items requiring dry storage;

- café – may provide both indoor and outdoor seating;
- toilets – include disabled facilities;
- wheelchair and pram access;
- play area – must comply with safety regulations. Contact your local council for advice on approved playground standards;
- display gardens – often designed and constructed by local landscapers in exchange for advertising their services and products to prospective customers;
- demonstration area – for gardening and craft demonstrations.

Figure 2.5: Many larger retail nurseries have cafés that allow customers to view plants, furniture and other products while they unwind with light refreshments.

Allow for comfortable customer movement within the indoor and outdoor sales areas. There should be enough space between display aisles and plant rows for comfortable browsing by groups of customers pushing plant trolleys.

Play areas

Play areas for children should also be considered as this will not only give customers more browsing time, but also save plants from being damaged by restless children. It is best to site the playground in a position where parents can easily keep an eye on their children.

Child-friendly ideas for nurseries include:

- play equipment that complies with safety regulations;
- sandpit;
- activity sheets for filling in at the nursery or taking home, suitable for a range of ages;
- miniature display gardens, featuring dinosaurs, fairies etc.;
- baby-change facilities;
- kids' gardening classes;
- competitions.

Equipment storage

Equipment, tools, potting mixes, fertilisers, pesticides and so on must be stored in secure lockable buildings or storage cabinets, conveniently located to the production areas.

Chemical storage

Chemicals should be stored in a separate dry area. Government health and safety regulations should be followed at all stages with regard to the handling, use, storage and labelling of equipment and chemicals.

Figure 2.6: All nurseries will require some sort of storage area for consumables. Plan ahead and have this in place at the set-up stage.

Production areas

The following can be included in production areas.

Mother stock area

Mother stock (also referred to as stock plants) are plants which are grown, usually in-ground, specifically for the purpose of providing a source of cuttings. This area should be positioned so that plants will be of the highest quality to give vigorous, disease-free cutting material. The ideal position is in well-cultivated fertile soil, with provision for adequate watering. In larger nurseries, mother stock plants are usually grown in a separate area; in smaller nurseries, plants in display gardens or the sales area are used for this purpose.

Propagation area

This area contains greenhouses, usually with bottom heating, and hardening-off areas. Depending on the climate and plants grown, this may include polyhouses without additional heating, shadehouses and fairly protected areas in the open.

Potting-up area

The potting-up area should be located near the propagation area. The area should be under cover and include provision for pots, soils, potting machines, benches and trolleys. It should also be conveniently located to storage areas to avoid having to shift potting media and pots etc. around the nursery. Hygiene is an important factor in potting-up, so the potting-up area should be cleaned and disinfected regularly.

Growing-on area

After hardening-off, plants are placed in blocks in the open until they are ready to sell. Depending upon the size of the nursery operation, the hardening-off area may be quite large.

Designing for effective environmental management

Modern nursery production requires careful environmental management, including responsible disposal of wastewater and minimal use of chemicals. A good nursery layout should incorporate features that promote effective environmental management.

Wastewater management

Nursery runoff can be a significant source of pollutants in natural waterways. Nursery runoff typically contains high levels of nutrients, such as nitrogen, phosphorus, iron and manganese, leached from containerised plants during irrigation. Nutrient-laden runoff in waterways contributes to toxic algal blooms and encourages the growth of aquatic weeds.

The discharge of nutrient-laden runoff is now restricted in many areas. Options for minimising the effect of nursery runoff include the following:

- establishing buffer strips of vegetation (grasses, trees and shrubs) around the nursery to intercept runoff;
- constructing dams to collect and store runoff;
- constructing reed beds to filter contaminants.

Careful siting of dams ensures that as much runoff as possible is collected for later use. The water may need to be treated to prevent algal blooms. Artificial aeration helps to control blooms by mixing water layers and increasing oxygen levels.

Other practices for minimising nutrient-laden runoff include:

- avoiding excessive fertilising. Adjust fertiliser concentration to plants' growth requirements; for example, feed less in winter when growth slows down;
- avoiding overwatering plants, especially in the first six weeks after potting-up when nutrient leaching is highest;
- using trickle irrigation instead of overhead sprays, which deliver a large volume of water and contribute to nutrient leaching.

Water recycling

Water recycling should be practised wherever possible, but in most cases wastewater must be treated before use to remove contaminants. Potential problems in using recycled water include excess nutrients, residual chemicals from herbicides and pesticides, and waterborne plant pathogens such as *Phytopthora* and *Pythium*. High levels of salinity and pH problems (overly alkaline or acidic) may also require treatment. Surveys have shown that, correctly treated, recycled water contains useful levels of nutrients which may reduce fertiliser applications by 20–30%.

Treatments used to purify water for recycling in the nursery include:

- filtration systems – to remove dirt and other debris;
- chlorine treatment – to kill algae and bacteria. Chlorine is added to water which has been pumped into a holding tank;
- algicides – these must be used with caution in recycling systems. Consult an appropriately qualified and trained operator;

- dilution with clean water – for example, dilute saline water with low-salinity water to bring it to a safe level for use on plants;
- acidification – acidifying agents are sometimes used to correct high pH levels in water but this should only be done by a qualified person using the appropriate equipment;
- reed beds – reeds and other aquatic wetland plants are grown in an artificially constructed bed filled with sand or gravel. Water moves horizontally through the pore spaces between the media and plant roots and remains below the surface. This technique has proved to be highly effective in reducing nutrient load in runoff, minimising the problem of algal growth in stored dam water and controlling waterborne pathogens over a period of time.

Hygiene: design factors

Prevention is the key to minimising pesticide and herbicide use. When planning the nursery layout, give some thought to the following:

- drainage – a good drainage system allows excess water to drain away quickly. A network of underground drains connected to a storage dam allows for water recycling;
- air circulation – promote good air circulation through the use of raised benches and permeable windbreaks;
- surfacing – hard surfacing materials, such as blue metal, paving, concrete and asphalt, are easy to keep clean and free of weeds;
- potting mix storage – potting mix should be placed in bins lined with concrete, not in direct contact with the soil.

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3

Propagation

Propagation is an important step in the nursery production process, since it is through this that plants are produced. Protected nursery environments are used in the production of plant stock for a wide variety of purposes including:

- growing-on to produce mature potted stock for retail and wholesale;
- transplanting to in-ground nursery beds;
- providing seedlings for horticulturalists such as landscape gardeners and market gardeners.

Figure 3.1: Some types of cacti are exceptionally easy to propagate, are low-maintenance and appeal to succulent enthusiasts.

Some nurseries choose not to undertake on-site propagation because it requires a high level of skill and is an area of commercial vulnerability. They find it easier to purchase rooted cuttings, tubestock or tissue-cultured plants, and simply grow them on for resale. As a result of this, there is a market for propagated stock in the nursery industry, and a niche exists for nurseries that choose to concentrate on propagation.

Propagators need to be highly conscious of the costs and benefits of their production methods since there is increasing industry pressure to keep product costs down and an ongoing need to achieve profitable returns. Production methods must be intelligent and take account of the return for labour input.

There are many different ways of producing plants, though most plants are produced commercially by either seed or cutting propagation. 'Tissue-culture' or 'micropropagation' techniques carried out in a laboratory are sometimes used where very large numbers of one plant variety are required quickly, or where limited propagation stock is available. Other plants (e.g. roses, deciduous fruit and ornamental trees) are traditionally produced by budding and grafting onto seed- or cutting-grown rootstocks. Division and separation are commonly used for the propagation of bulbs and herbaceous perennials.

Other propagation techniques (e.g. layering or marcotting) may be important in the propagation of specific types of plants; but they are relatively insignificant overall in the nursery industry.

Sexual propagation

Sexual propagation involves growing a plant from a seed or spore which has been produced by fertilisation of a plant's female part by its male part. Plants grown this way can have characteristics of both parents. A sexually propagated plant is not always exactly the same as the plant from which the seed or spores were taken. Most flowering annuals, vegetables, biennials and perennials are grown this way. Ferns and some trees and shrubs are also propagated sexually in the nursery industry.

Figure 3.2: Aerial layering is one method of producing plants that are genetically identical to the parent stock.

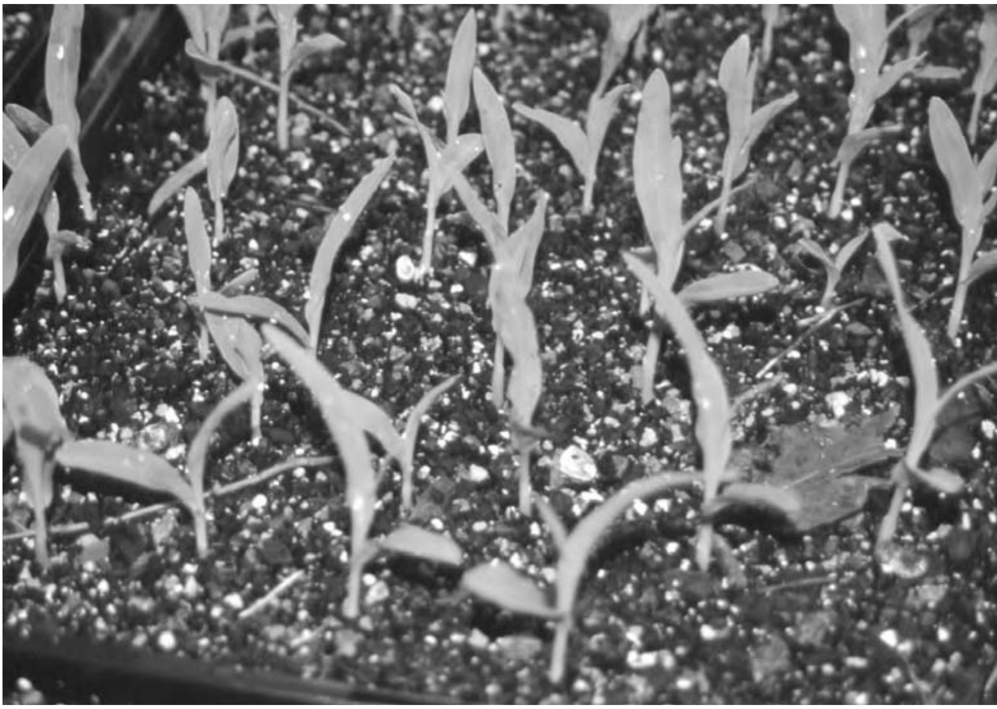

Figure 3.3: When propagating from seed, the depth of planting is critical. The seed has limited energy stores so, to achieve maximum germination, sow seed at the appropriate depth for that species.

Dormancy factors affecting germination

In their natural state, many species have adopted mechanisms that defer germination. This process is called dormancy. Seeds from some plants are more difficult to propagate than others because dormancy is induced by a variety of mechanisms, for different purposes. Some seeds utilise more than one mechanism. For many 'difficult-to-germinate' seeds, it is possible to carry out some type of pre-germination treatment which will increase propagation success rates. Understanding different seed dormancy mechanisms can assist growers in propagating a variety of seeds.

Dormancy mechanisms are induced by seed coats, seed embryos and environmental conditions. Dormancy induced by seed morphology is referred to as primary dormancy. Dormancy induced by environmental conditions is referred to as secondary dormancy.

Primary dormancy

Dormancy induced by the seed coat includes:

- physical dormancy mechanisms such as hard seed coats that inhibit the entry of water and oxygen to the seed embryo. In nature these hard layers are softened by environmental effects such as freezing and thawing, mechanical abrasion, attack by micro-organisms etc. This condition is characteristic of many plant families, including *Fabaceae*, *Malvaceae*, *Geraniaceae* and *Solanaceae*;

- mechanical dormancy induced by the seed covering being too hard to allow the embryo to expand when germinating (e.g. in a peach stone);
- chemical inhibitors in the seed coat preventing germination until the inhibitors have been neutralised. This is common with fleshy fruits and berries. Seeds of this type usually need to be removed from the fruit and washed before sowing.

Dormancy induced by the seed embryo includes:

- chemical inhibitors in the embryo preventing germination until the inhibitors have been neutralised;
- embryo immaturity at the time of fruit ripening. This is common in the following families: *Araliaceae, Ranunculaceae, Ericaceae, Primulaceae* and *Apiaceae*.

Secondary dormancy
Secondary dormancy includes seed germination responses such as chilling requirements or particular climatic sequences. An important aspect of secondary dormancy is that seed can be induced into dormancy by unfavourable conditions such as inadequate water or inappropriate temperatures. This is common in the *Rosaceae* family.

Seed storage

The process of growing plants for seed production can be long and requires intensive management. Although some nursery managers may need to save their own seed to maintain particular genetic stock or ensure the availability of rare species, most nurseries don't harvest their own seed. Even for growers not collecting their own seed, however, proper seed treatment is essential in maintaining seed longevity and viability. Seed should be dried quickly to prevent spoilage, but exposure to excessive temperatures or radiation can kill the living embryo.

Seeds of some plant species naturally have a greater longevity than those of other species, and germination can be affected by dormancy mechanisms. However, germination can also be affected by seed storage methods. Correct storage of seed is important in ensuring seed longevity and viability. Storage methods should aim to maintain seed in constant conditions and safe from damage or contamination by pests and diseases. Optimal seed storage techniques vary according to the condition, composition and physiology of individual species.

The two most important variables in seed storage are moisture and temperature. Other factors, such as oxygen and carbon dioxide levels, can also have some influence.

Moisture
Moisture levels are important both in terms of relative humidity and moisture levels within the seed itself. High relative humidity during seed collection and processing can result in seeds that are not completely dried before storage. Seeds that are stored in high relative humidity conditions are more susceptible to rot and fungal infestation, can germinate prematurely (while still in storage) and may have reduced longevity. Likewise, large fluctuations in relative humidity reduce seed longevity.

Moisture content within the seed itself varies among species and throughout the life-cycle of the seed as well. Some seeds (particularly short-lived seeds such as citrus) will lose their viability if they become excessively dry. Most seeds respond well to drying, however, and as the moisture content of a seed is lowered the seed longevity is increased.

Industry professionals hold different opinions, but 6–8% moisture content is generally considered optimal in most seeds. Grains are frequently stored at around 15% seed moisture. Between the moisture ranges of about 15–5%, every 1% reduction in seed moisture doubles the life of the seed. Some seeds, particularly legumes such as peas and beans, are susceptible to excessive hardening if they become too dry (below about 7% moisture content). These 'hard seeds' germinate poorly. Soaking such seeds, or storing them in a high-humidity environment for a few weeks prior to planting, can improve viability.

Removing moisture from seeds is done by lowering the relative humidity of the surrounding air, which can be done by refrigeration or desiccation. Refrigerated air is both drier and cooler than room air. Seeds must equilibrate with 65% relative humidity (or less) for 1-year storage, 45% for 2–3 year storage and 25% for long-term storage (5–6% seed moisture content). Dry seeds (<14% moisture) can be stored in the freezer, but they must be in moisture-proof containers. Reasonable storage conditions for several seasons can be provided by storing envelopes of fully mature and dry seeds in heavy ziplock bags in the refrigerator. Longer storage requires more ideal conditions.

Temperature

Seeds need to be stored at appropriate temperatures for maximum longevity and viability. Good seed storage results have been achieved when temperatures are kept at around 4°C (40°F). Each 10% reduction in temperature (down to 0°C or 32°F) doubles seed life.

Other factors in seed storage

When temperature and moisture levels are controlled, other factors such as oxygen and carbon dioxide levels generally do not have a significant effect on seed longevity and viability. Grains are sometimes stored in a carbon dioxide atmosphere to control pests. Storage in high carbon dioxide environments has been shown not to affect germination.

The tetrazolium test for seed viability

In this test, a colourless liquid is imbibed by the seed. The chemical goes through a reaction (reduction) in living tissue and produces a red substance which cannot be diffused – hence any living parts of the seed turn red or pink, and any dead parts remain unchanged. The chemical used is a 1% solution of 2.3.5 triphenyl-tetrazolium chloride (bromide).

The test is conducted by cutting a seed in half so the embryo can be seen. The seed is then soaked in the solution (at a temperature of 20–30°C (68–86°F) for 12–24 hours in the dark. The seed is then studied, by hand lens if necessary. Seeds can be selected at random from a batch and tested to give an indication of overall viability.

Asexual propagation

Asexual or vegetative propagation involves producing a new plant from a sole parent. A part of an existing plant, such as a piece of stem, leaf or root, is treated so that it can produce a new plant. In asexual propagation, the parent plant and offspring are genetically identical. A range of techniques can be used for asexual propagation.

Runners

Runners are shoots that grow along the ground from axillary buds and produce roots at the nodes. Plants such as strawberries are produced from runners.

Suckers

Suckers are new shoots that develop from the root of the parent plant. Suckers can be divided when they have developed independent root systems. Plants such as raspberries can be produced from suckers.

Layering

Layering is the process of producing roots on the stem of a plant. There are several forms of layering:

- tip layering is the development of roots on the growing tips of stems. This form is used to propagate blackberry, raspberry and boysenberry;
- simple layering is the development of roots along growing stems. This form is used to propagate honeysuckle, filbert, spiraea, rhododendron and magnolia;
- trench layering or etiolation layering involves pegging down new shoots so that they develop roots. This method is used for fruits and nuts such as apple, pear, filbert and walnut;
- mound or stool layering involves burying the bulk of the parent plant so that roots form along the stems. This method is used for apple stock, cherry stock and currant;
- air layering is the development of roots on aerial stems through specific management methods. This technique is utilised for figs, monstera, philodendron, camellia, rhododendron, azalea, holly, magnolia and lilac;
- compound layering is the process of producing layers multiple times along the one shoot. This method is used for grape, philodendron, wisteria, magnolia and lilac.

Separation

New bulbs and corms produced vegetatively are separated from the parent plants to provide new propagation stock. Bulbs produced in this way include hyacinth, lily, narcissus and tulip. Corms produced this way include gladiolus and crocus.

Division

Particular root structures such as rhizomes, tubers and clumping crowns are suitable for division. Rhizomes include canna and iris; offsets include leek, pineapple and date; tubers include potato and dahlia; crowns include phlox.

Grafting

This involves taking a section of stem from one plant and attaching it to another plant in such a way that the two will grow together. Grafting enables you to change the variety of an existing plant. For example, by attaching a new variety to an existing root system you can remove the old top and have a plant comprising the roots of one variety and the top of another. Plants which can be grafted include apples, pear, peach, almond, citrus, avocado, camellia, ash, birch, elm and walnut.

Cuttings

A cutting is a piece of root, stem or leaf which has been treated in a way that stimulates it to grow roots, stems and leaves; hence producing another new plant. While there are different types of cuttings, the majority are pieces of stem, often with some leaves left at the top.

Cutting propagation can be carried out on a very wide variety of plants and, second to seed propagation, is the most common method of producing new plants. Cutting propagation is most commonly used for shrubs, indoor plants and many herbaceous perennials. It is not generally used to propagate most types of trees.

- Root cuttings – *Albizzia julibrissin, cydonia*, apples, some poplars, rhus, liquidambar, wisteria.
- Stem cuttings:
  - hardwood (in winter) - quince, rose, grape, fig, many deciduous plants;
  - semi-hardwood (in autumn) – lemon, camellia, holly, grevillea, azalea, many woody shrubs;
  - softwood (in spring) – magnolia, weigelia, spiraea, oleander, maples;
  - herbaceous – geranium, coleus, chrysanthemum, many perennials and herbs.
- Leaf cuttings – begonia, sanseviera, african violet, peperomia, gloxinia;
- Leaf bud cuttings – ivy, rhododendron, boysenberry.

Cuttings are usually planted into a mix of materials such as sand, peat moss, perlite, rockwool or vermiculite. Part of the tissue is usually below the surface of the mix, and

Figure 3.4: *Murraya paniculata* cuttings showing root development over a six-week period.

some exposed above the surface. The cutting must be kept in optimum environmental conditions for that particular plant. Humidity, temperature, light, water and other factors all affect the success of the cutting.

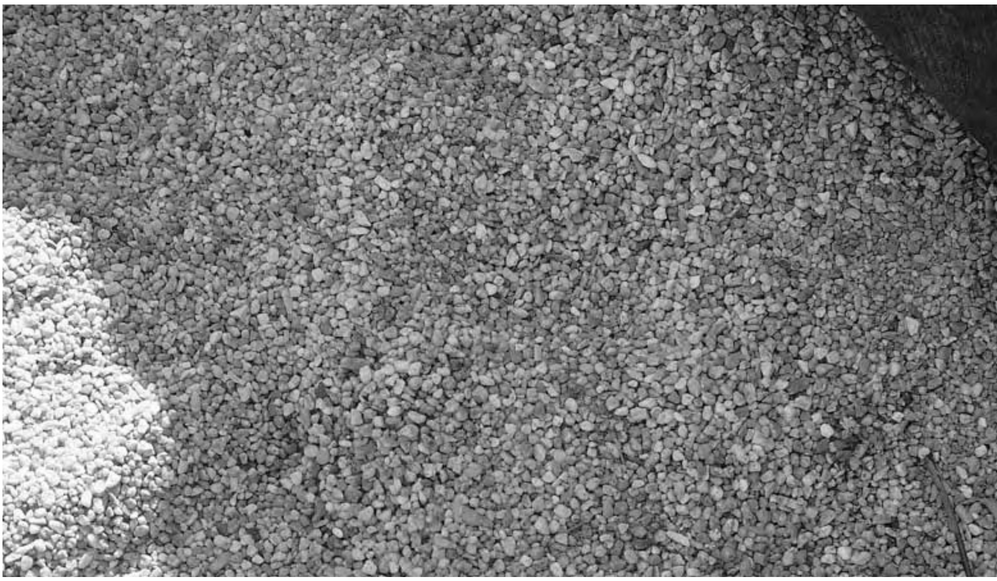

Figure 3.5: Propagation sand used for striking cuttings.

Hormones and cutting propagation

Chemical hormones may be applied to stimulate the formation either of roots or foliage/shoot growth. Pesticides or disinfectants may be used to reduce the risk of pest and disease outbreaks. Heating may be used to warm the root zone (bottom heat) and encourage faster growth of roots; periodic misting of the foliage will cool the top of the plant or prevent dehydration of the foliage. Five major hormone groups often referred to are auxins, cytokinins, gibberellins (GA), abscisic acid (ABA) and ethylene.

Figure 3.6: Commercially produced plant hormones such as this powder can help to stimulate root development on cuttings.

Auxins are involved in a variety of things including stem growth, root formation, inhibiting lateral bud development, fruit and leaf abscission, fruit development and activating cambium cells. Of all the hormones, auxins have the greatest effect on root formation in cuttings. Root formation and development in a cutting typically follows the pattern outlined below:

- auxin active stage – auxin is supplied continuously for root cells to form (lasts several days or longer). This auxin is supplied through chemicals generated by the terminal bud, or through chemicals applied by the propagator to the root zone;

- auxin inactive stage – auxin is not required for several days after root formation has started;
- root elongation stage – root tip grows outwards, breaking through the outer layer of cells at the base of the cutting and forming a root.

The three most commonly used auxins are:

- indole 3 acetic acid (IAA) – occurs naturally, but is less effective than IBA or NAA in promoting root growth;
- indolebutyric acid (IBA) – artificial; the most widely used rooting hormone, used on its own or in combination with NAA;
- napthaleneacetic acid (NAA) – artificial; used on its own or in combination with IBA.

Auxins can be applied to plants as a powder, gel or liquid. Cuttings are frequently treated with hormones which encourage root development. The strength of hormone depends on such factors as the type of cutting being struck, the variety of plant and the application method.

Powder is easy to apply; it comes in specific concentrations and you don't need very much expertise to use it. Its major disadvantage is that you are usually restricted to the predetermined strengths available.

Liquid hormones offer greater flexibility, because the concentration can easily be varied by adding an appropriate liquid. The length of time for which the cutting is dipped (and exposed to the hormone) can also be varied. For example, basal parts of cuttings can be soaked for 24 hours in a dilute solution (e.g. 100 ppm), or dipped in a concentrated solution (500–10 000 ppm) for about 5 seconds.

Gel remains on the cutting and its strength can be adjusted somewhat. Other ingredients, such as vitamins, are sometimes included in the gel.

Cytokinins are hormones which help with cell differentiation. Certain cytokinins applied to some plants at specific rates can actually help with root initiation, though more generally cytokinins are found to inhibit root development. Cytokinins strongly stimulate the development of buds and are used in tissue culture to stimulate leafy growth.

Giberellins are another type of plant hormone. At high concentrations, gibberellins inhibit root formation. If naturally occurring levels of gibberellin are lowered, root development should be improved. Chemicals such as 'Alar' and 'Arrest' are commercial preparations which work by interfering with the effect of gibberellin in a plant, hence reducing the inhibition to certain types of growth.

Gibberellins are sometimes used as a means of overcoming seed germination inhibitors. Gibberellins available for sale include:

- paclobutrazol – sold as a 4 g/L suspension under the brand name 'Bonzi', it is absorbed by leaves, stems and roots. The hormone moves to just below growth tips and inhibits gibberellin production, causing reduction in vegetative growth, and stimulation of flowering in some species. Chlorophyll content can be increased, causing darker-coloured foliage;

- daminozide (Alar) – mainly absorbed through leaves, therefore best applied under slow drying conditions. It also slows and reduces the amount of cell expansion, causing shorter internodes, and reduces dominance of apical tip, causing more branching. Chlorophyll can be increased, causing darker-coloured foliage. The use of Alar has been banned in some countries due to health concerns;
- chlormequat (Cycocel) – an anti-gibberellin, causing reduced internode spaces on sensitive plants.

Abscisic acid (ABA) is a naturally occurring compound that plays an important role in inhibiting germination of many types of seeds, particularly those with immature embryos. ABA applications have been used to inhibit the germination of non-dormant seeds, and to offset the effects of gibberellic acid applications.

Ethylene is a gas produced by most plants in small quantities. When large amounts of vegetation are enclosed in a poorly ventilated space, the effects of ethylene can become significant. This may damage the plants, normally detected by thickening of stems. In some cases ethylene gas is purposefully applied to plants to cause a desirable effect; for example promoting flowering in bromeliads, or causing foliage to drop from deciduous plants hence bringing them into dormancy and market-readiness. Ethylene has also been used to overcome dormancy in some seeds.

There are many other hormone treatments used in nurseries, but they are generally highly specific, working on a limited number of plant varieties and used only by nurseries which are big enough to make the practice economically viable.

Anti-transpirants and cutting propagation

Anti-transpirants are waxy materials sprayed over cuttings to stop the leaves drying out before the cutting starts to form roots. These have been used in the US and more recently in Australia, both to aid propagation and to help rooted cuttings adjust to a harsher environment after being potted-up and moved outside.

When sprayed on plants, anti-transpirants can reduce water loss by 50%. They are particularly useful when transplanting, for root disturbance in potted plants means they cannot take in enough moisture to retain foliage. Once sprayed on the leaves, anti-transpirants will expand with leaf growth and do not harm or restrict the plant for the 1–2 months before breakdown. Although anti-transpirants are not yet widely used in nursery situations, they are becoming more attractive to reduce water usage as well as frost damage.

Aseptic micropropagation (tissue culture)

Small sections of plants are grown in a laboratory. As they grow they can be transplanted to individual containers and eventually into soil containers. Also known as tissue culture, this technique is becoming increasingly important in commercial nurseries.

Tissue culture basically involves growing plants from single cells or from small pieces of plant tissue. It involves multiplying plants under sterile laboratory conditions. Very roughly speaking, a section of a plant is placed in a nutrient environment (e.g. a jelly impregnated with the nutrients essential to plant growth) then left in a pathogen-free environment where conditions such as temperature, moisture and light are controlled.

Figure 3.7: Tissue culture set up for producing plants aseptically.

After a period of time the microscopic section of plant will grow. Eventually it can be moved (via a series of stages) into the outside environment.

Tissue culture is of increasing importance in the nursery industry. Its commercial potential has rapidly developed over the last two decades, and now many plants sold in nurseries are propagated using this technique. Some plants are much easier to produce by tissue culture than others.

The main advantages of tissue culture are:

- propagation of difficult species. Some things which have proven extremely difficult to grow other ways have been grown in large quantities via tissue culture;
- plants can be propagated at any time of the year using tissue culture techniques;
- the ability to propagate rapidly. If a new hybrid has been developed, it can take several years to produce enough individual plants of that hybrid to make it worthwhile marketing it. Using tissue culture it is possible to produce tens of thousands of specimens of the new hybrid within a year. In woody species, breeding and selection by sexual hybridisation has been slow because of the long periods of time between each generation. Tissue culture can speed this process considerably;
- considerable savings in time and space compared with those required by conventional procedures;
- disease-tested material can be bulked in large quantities without the costly precautions that are otherwise needed to prevent reinfection during propagation. Plants such as lilies, strawberries and potatoes, while not necessarily difficult to propagate conventionally, are very susceptible to viruses.

These advantages can be offset by problems inherent in the tissue-culture method. These include:

- plants need to be hardened-off slowly under high shade and high humidity (misting) conditions, then gradually eased out into normal conditions. On planting out, however, you can sometimes get:
  - abnormal or no root growth;
  - plants prone to dry out quickly;
  - reduced photosynthetic activity if the propagation was done in a sugar-enriched environment;
  - sometimes, an induced dormancy;
- only a relatively small proportion of plant species can be cultured well enough to be effectively propagated. The time and expense in developing the required technology may not be worthwhile for minor species. Even when it has been developed scientifically for a particular species, it is often not taken up commercially;
- compared with a conventional propagating bench, a tissue-culture laboratory requires a large capital investment with correspondingly higher running costs. Labour is the largest single item of expenditure.

Propagation efficiency

A skilled propagator can propagate large numbers of plants very quickly and with minimum losses from disease, rough handling, poor techniques and so on. If a propagator can get cuttings to strike faster, seed to germinate quicker or more fully or grafts to 'take' (grow together) sooner, then the plants are produced in less time, take up less space in the nursery and require less nurturing; hence profitability can be increased significantly. The quality and quantity of work achieved by a propagator can vary greatly. It is not uncommon for one good propagator to produce the same as three less-competent propagators at another nursery.

Improving propagation efficiency

There are several factors which affect the efficiency of producing seedlings or rooted cuttings. Different factors will be of more or less significance depending on your location, product range, production methods and business operation. The following questions will help you assess various key factors that contribute to propagation efficiency:

Quality of work and materials
General

- Have propagating equipment and containers/trays been cleaned/sterilised?
- Has the propagating mix been mixed thoroughly and sterilised?
- Have the seeds or cuttings been correctly labelled?

Cuttings

- How well is the cutting prepared and planted?

- Has the propagator damaged the cutting material excessively? This would increase the likelihood of pest or disease damage.
- Has the correct amount of leaf been removed?
- Has the cutting been placed in the propagating media properly?
- Has the cutting been treated in a way which will minimise drying out throughout the cutting operation?

Seed

- Has viable seed been used?
- Has the seed been adequately processed (e.g. separated from fruits or pods)?
- Has the seed been sown evenly and at a suitable density? Seeds sown too heavily will be overcrowded and consequently of poorer quality. Seeds sown too thinly waste valuable space and materials.
- Has the seed been sown at a suitable depth? More seeds are lost from sowing too deeply than by sowing at too shallow a depth. Seeds sown deeply will also take longer to emerge after germination. A seed only has a certain amount of stored resources to allow it to germinate and reach above the soil. If a seed is sown too deeply, it will run out of resources before it emerges and can photosynthesise, or result in a weak seedling.

Selecting the most appropriate technique
General

- What time of the year is the operation carried out?
- What type of propagating media is used (e.g. sand/peat, sand, vermiculite, growool, open ground, perlite bed, gravel bed, nutrient agar)?

Cuttings

- What type of cutting is used (e.g. semi-hardwood, hardwood, softwood, tip, older wood, leaf bud, leaf, root, 4 cm/1.5" long, 6 cm/2.5" long)? Is this the most appropriate type for the plant?
- What additional treatments have been carried out on the cuttings (e.g. hormones, disinfecting drenches)?

Seed

- Has a suitable pre-germination treatment been used (e.g. scarification, stratification, hot water)?

Aftercare

- Where are the seed trays or cuttings placed after planting? Are they outside exposed to the elements, in a glasshouse, in a cold frame, in a hotbed?
- How frequently are they watered? Are they watered by hand, by manual sprinklers, or by automatic sprinklers?

Growth stimulation

- Have any techniques been used to stimulate germination or root growth (e.g. bottom heat, wounding, intermittent misting, fogging)?

Cost-effectiveness
Cost of materials used

- Are the seeds or cuttings placed in a pot, in a bed or in the ground?
- How many seeds or cuttings can be fitted into a particular space? More cuttings or seeds per unit space is more cost-efficient as long as you don't overcrowd.
- How much do the materials cost? This includes cost of pots, propagating mix, labels, hormones, greenhouses, hotbeds etc.

Labour cost

- Do you have ready access to propagation material? Consider the time involved in obtaining seed or cuttings.
- How many seeds can you sow, or cuttings can you prepare and plant, per hour?
- What time is involved in aftercare, such as watering, weeding, spraying and fertilising?
- Are the propagation greenhouses close to the propagating area? Does it take time to transfer cuttings or seed trays from one area to another?
- Variety of plant (some plants may require more attention than others to look after).

Success rate

- What proportion of seeds germinate, or cuttings planted actually form roots?
- How long does it take for the seeds to germinate or for cuttings to form roots?
- This must be related to the cost of the space. Do the cuttings or seed take up a lot of space in a hotbed? Consider that the hotbed costs money to buy and to run. The seed which germinates more quickly or cuttings which strike faster are generally less expensive to produce.
- Variety being propagated (some varieties of plants are more likely to be successful than others).

All these factors, and others, will have a bearing on the cost of producing a plant from seed or by cutting. Some of these factors will be more significant than others. Some may account for 10, 20 or 30% of the cost; others might only account for a very small proportion of the cost.

Disinfectants

Hygiene is a particularly important aspect of propagation, as it can greatly increase the success rate of propagation work. Disinfectant chemicals are used widely in nurseries for cleaning tools and work areas such as benches and floors. They may also be used for washing pots or trays before reusing, and in an appropriate strength for dipping cuttings before planting. These practices can all significantly reduce pest and disease problems. One of the most common and effective general-purpose disinfectants is common household bleach (sodium hypochlorite), normally used at a 0.5–2.0% available chlorine concentration. At this concentration tools or plant containers can be dipped or sprayed and surfaces washed. The concentration must be very precise when plant tissue is treated, as too strong an application can damage plant tissue.

Medical disinfectants such as Dettol, Biogram or alcohol can also be used, but these may be cost-prohibitive for cleaning large areas. Methylated spirits is sometimes used at the workbench for dipping tools when taking cuttings. Various other methods may be used to disinfect greenhouses, work areas, equipment or materials, ranging from steam treatment (which is very environmentally friendly) to the use of extremely dangerous gases such as methyl bromide or chloropicrin. Gas treatments should only be carried out by skilled operators, and the treated section of the nursery should be evacuated both during and after treatment, for a recommended period of time.

PRACTICAL EXERCISE

Propagation efficiency is a crucial factor in the profitable management of a propagation nursery, and production costs are an integral element of this efficiency. The following practical exercise will assist you in evaluating your propagation costs.

Prepare a pot of cuttings or a tray of seeds and estimate the cost of production for each plant produced.

1. Write down step by step what is to be carried out:
   - obtain propagating material;
   - assemble materials (containers, media, labels);
   - prepare and plant cuttings or sow seed;
   - water and place in greenhouse;
   - aftercare – 'x' months, watering, fertilising, pest and disease control etc.
2. List the materials/equipment required and estimate their cost.
3. Prepare several pots of cuttings, or trays of seeds. Time yourself. Note how many cuttings have been placed in each pot, or seeds sown in each tray/container.
4. Estimate the aftercare time expected. Estimate the proportion of cuttings you expect to strike, or seeds to germinate.
5. Estimate the cost of producing one plant by cutting or from seed (using the material/equipment costs and labour requirements established in the previous steps). This will require you to set an hourly rate for your labour costs. Be realistic, and don't forget you have to include a labour-cost component to cover all the extras such as compulsory superannuation or health cover, payroll taxes, holiday pay etc.

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Potting and transplanting

There are normally four stages in nursery plant production: propagation, transplanting, growing-on and marketing the fully grown plant. Each stage requires specialised skills. Large nurseries have the luxury of allowing staff to specialise in one or two of these stages, but smaller nurseries need to employ experienced staff or train staff to be competent in all stages of production. Propagation is a particularly specialised skill and is discussed in chapter 3.

Transplanting

Following propagation, nursery plants are transplanted to appropriate growing media. Transplanting is the taking of newly propagated plants from the propagating media and placing them in a growing media of some sort, in a manner that minimises damage or reduces any setback in growth of the transplanted plant. It is not always straightforward, particularly with tissue-cultured plants. When a plant is taken from one environment to a different one it may experience shock, which under extreme circumstances can cause the plant to die. You must pay careful attention to where plants came from and ease them into their new environment. The nursery must have facilities to do this (e.g. greenhouses, shadehouses and heating).

Tissue-cultured plants are the most difficult to transplant and establish in soil. Plants taken from a greenhouse, or propagated in a warm climate and moved into areas with cooler climates, can also be difficult to establish and maintain. Two critical factors at this stage are cleanliness – so you don't expose the plant unnecessarily to diseases or pests – and a good-quality growing media which will support the plant until it sells. Various types of growing media are discussed in chapter 8.

Transplanting seedlings

Ideally, seedlings should be transplanted as soon as possible after they have emerged. This will vary to some degree according to the type of plant you are growing. Species with larger seedlings can generally be handled earlier than smaller ones. Normally seedlings will be transplanted once the first or second true leaves have appeared.

Trays or flats of seedlings can be removed to a protected propagation area still in their containers. They should be well-watered and, if possible, allowed to drain for a short time prior to lifting. The seedlings can then be carefully lifted from their containers and gently pulled apart, taking great care to minimise damage to roots. Retain as much of the propagating media as possible around the roots, and remove only small clumps or groups of seedlings at a time to prevent roots drying out excessively.

Seedlings grown in-ground or in large beds to be grown-on in containers can be carefully lifted immediately before transplanting and quickly transferred to a protected area for transplanting. These seedlings can be kept moist by temporarily storing them in a container of water, a plastic bag, or other moist materials. If possible, lift only small amounts of these seedlings to ensure that they are not exposed for any length of time.

The containers (flats, pots, punnets) in which seedlings are to be grown-on should be sterilised and filled with a suitable growing media, not quite to the top. A hole is made in the medium with a dibble-stick of some sort, and the roots of the seedling are inserted into the hole. The growing media is pressed lightly around the roots to ensure good contact. For large flats or containers, dibble-boards can be used to make large numbers of holes simultaneously. The transplanted seedlings should be watered immediately and placed in a protected growing-on environment as soon as possible.

Transplanting cuttings

Rooted cuttings can be transplanted in a similar manner to seedlings. Containers of cuttings are removed from propagation areas and the cuttings are carefully ‘knocked’ out of the container. If root development is evident, cuttings can be carefully pulled apart, retaining as much propagation media as possible around the roots. Cuttings with sufficient root development can be transplanted into suitable containers as with seedlings, while cuttings with little or no root development can be placed back into propagation media and returned to the propagation house or area. Cuttings with obvious rotting of base or stem should be discarded. All cuttings, struck or unstruck, should be watered thoroughly immediately after transplanting.

Potting-up plants

If you leave a potted plant with the same growing medium for too long, the plant will begin to suffer. This principle is true of newly germinated seedlings as well as established container-grown plants. Likewise, potting-up plants can lead to improved plant health or vigour.

Plants are potted for a number of reasons:

- they are getting too big in the pot they are in and need more room to grow;
- you want them to grow faster, to produce a larger plant in less time;

- you want the plant in a different container, to replace a broken pot or use one that looks better or is more functional;
- you want to root-prune the plant. This promotes the development of new healthy feeder roots. Root-pruning may also be undertaken to remove diseased roots;
- you want to put the plant into a better growing medium;
- you want to re-pot a bonsai, topiary or specially shaped plant;
- you want to transplant plants from an in-ground location into a pot.

Figure 4.1: Different pots have different properties. For example, terracotta pots tend to be absorbent and dry out more quickly than plastic pots.

Removing the plant from the container

- For small to medium containers, tip the container upside down and gently shake it. If this does not work, tap the ridge of the pot on the edge of a wheelbarrow or bench.
- The rootball should be moist before removing it from the container.
- If the plant is potbound, soak it (immerse) thoroughly in water first. Put the entire pot in a larger container of water and wait for all bubbling to stop.
- Large pots may need to be cut away from the plant.

Potting machines

Potting machines were developed to reduce the manual labour and to increase efficiency of labour with a greater output. Potting machines may be simple, assisting with supplying potting mix to the pot, or complex, carrying out a large part of the overall potting operation. There are many different systems available.

Potting machines can carry out or assist with any number or combination of the following tasks:

- filling the pot with potting mix – usually achieved by dropping mix from a mechanically filled hopper above. Mix can be dropped manually or automatically and, if required, in predetermined quantities;
- placing or holding a plant in position as potting mix is filled around it;
- the plant might be extracted automatically from standard-sized propagation containers such as plugs used for vegetable or flower seedlings, or fed by hand into the machine;
- feeding pots one at a time into the machine. The pots might be lined up onto a conveyor by hand, or taken from stacks mechanically one by one and fed onto a conveyor;
- transferring potted plants away from the machine. Once potted, the plants might be placed manually or automatically onto a conveyor which takes them to a point from which they can be loaded onto barrows or trailers and carried to growing-on areas.

Figure 4.2: Potting mix containing compost and pine bark. Larger nurseries may produce their own potting mixes; small nurseries may find it cost-effective to buy pre-mixed growing media.

Potting machines can be one of the most important investments for any nursery. The cost of these machines depends on their features. Before even looking at machines, it is essential to determine exactly what functions you want one to perform. Potting machines can be considerably expensive to purchase, but they can greatly decrease the wages bill in a nursery. A good potting machine can often halve the number of staff needed in a nursery.

Problems with potting machines

Potting machines are never an entirely automatic operation. Things can go wrong, and a skilled operator should monitor them, feed in the raw materials (plants, pots and potting mix) and take the potted plants away. Possible problems include:

- high wear and tear caused by working with abrasive soil components, such as sand;
- variation in pot sizes can prevent successful pot separation. When a pot-separating device is being used, get samples from your pot supplier and check that they work before buying the machine. Same-size pots from different manufacturers don't always separate equally well;
- variable quality of potting media. In many types of machines, potting media needs to be of uniform quality to work;
- potting speed may not be appropriate for your needs;
- staff access to the machine may be limited. Limited accessibility can cause congestion, particularly if several people are working around the machine at the same time;
- container sizes to be handled might not be appropriate for your nursery;
- the machine may not fit comfortably into your working area. Is your shed big enough and can staff move around the machine easily?

Potting bedding-plant seedlings

In a commercial nursery, bedding-plants are annuals that are germinated in a hothouse out of season, then potted-up at seedling stage and sold at bud stage ready to plant out and provide mass colour. At the end of the season they are discarded.

Bedding-plant seed is sown in late winter and maintained at a temperature of 20–22°C (68–72°F). When the first set of true leaves is open, the seedlings should be pricked out and planted into cell trays filled with a good-quality seedling-raising mixture. Handle the seedlings by the leaves, not by the stems. The seedlings should be well-watered and kept in the shade for the first 3–5 days at a reduced temperature of 15°C (60°F).

Potting trees and shrubs

Trees and shrubs can be potted at most times of the year, ideally when the plant is actively growing. Remember that there may be some transplant shock, and a recovery period may be required afterwards. Potting can cause flowerbud drop. If you want flowers, it is best to wait until flowering has finished before repotting. If you pot in summer, the plant may suffer from water stress and will need to be closely watched for a few days. It might be better to wait until after warm weather.

- Don't pot-up in windy or sunny places – plant roots can dry very rapidly.
- Pot in a clean place (a clean shed or on a washed concrete base) to minimise disease problems.
- Don't pot on a very hot day.
- Put plants into a cool protected position for at least a few weeks after potting.

Potting bare-rooted plants

Juvenile and semi-advanced plants from in-ground nurseries are frequently lifted for transplanting in a bare-rooted state. This particularly includes many deciduous plants such as grafted fruit trees, ornamental trees and roses. Bare-rooted plants are most frequently sold for planting directly in-ground, but can also be suitable for transplanting into pots. These are lifted predominantly when the plant is in a dormant state during mid to late winter, when the plants will suffer minimal transplant shock.

Plants can be inspected at this stage and those with diseased or damaged roots can be discarded or root-pruned. Plants with large root systems are sometimes pruned to promote ease of handling (transporting, replanting). Plants that are to be replanted fairly quickly can be easily bunched in bundles of 10 or more to assist ease of handling. Plants with an indefinite time before replanting (e.g. plants sold to retail nurseries) should have their roots protected to prevent them drying out. Materials such as moist sawdust can be packed around the roots to provide temporary protection. Bare-rooted plants are often kept in refrigerated storage until planting time.

Potting-up bare-rooted plants is a reasonably simple procedure, but some care needs to be taken.

- Roots should be soaked before potting.
- Following initial plant manicuring, roots should not be pruned before replanting (diseased tissues should be removed).
- Care must be taken when fertilising bare-rooted plants to avoid damaging new root growth.
- Newly potted bare-rooted plants should be kept moist and protected.

Dividing plants

Dividing plants is the process of splitting the rooting material of a mature plant into sections in order to produce several new plants. The greatest danger is ripping or bruising plant tissue, letting infection into those parts. Most clumping perennial plants are best divided by using two forks sunk into the clump, then rocked apart as the clump is eased into two parts. Any torn parts should be cut clean with a sharp knife, and dusted with a suitable fungicide to prevent infection.

Potting a small plant into a larger pot

When you see roots emerge from the bottom of a pot plant, it is time to repot into a larger container. The correct procedure is described below.

1. Select a pot that is slightly larger (not too much bigger) than the current pot.
2. Gently remove the plant from the smaller pot. If the plant will not come out easily, slide an old kitchen knife around the edges of the pot. If it still won't come out, you may have to break or cut the pot.
3. Loosen any tangled and circling roots. Prune the roots if necessary.
4. Place a layer of quality potting mix at the base of the new pot.
5. Place the plant in the centre of the new pot. The soil level should be approximately 25 mm (1") below the top of the container.

6 Fill the sides of the container with potting mix, firming it down as you go.
7 Thoroughly water the pot. This will help remove any air pockets.
8 Cut back any dead or diseased foliage and prune to shape.
9 Apply a slow-release fertiliser.

Porous pots need different treatment

Some pots, such as wood or terracotta, dry out more easily than others because they soak up moisture from the potting mix. These pots can be attractive sales features and may suit some plants that like dry conditions, but they can be problematic with plants that require moist soil. Different techniques can assist in achieving pleasing results with porous pots:

- use a potting mix specially designed for terracotta pots – these include materials that retain water for longer;
- add peat to the potting mix (soak the peat first so that it can absorb water);
- add water crystals to the mix;
- cover the surface of the mix with mulch (small pebbles or a fine bark mulch);
- avoid using porous pots in positions where they will be exposed to high levels of solar radiation, winds or other evaporative elements.

Growing-on

As plants grow to a saleable size they must be protected from harsh environments, pests and diseases. These factors can cause plant damage which reduces saleability. Careful consideration must be given to plant location. The surface below pots should be well-drained and clean, preferably slightly sloping concrete or asphalt or, if finance is limited, gravel or weedmat. Watering, fertilising, regular spraying, pruning, staking and anything else needed to bring plants to a marketable size are all important components of this stage of production.

Spacing

When growing plants on and displaying marketable stock, you must decide how much space to leave between individual pots. There are arguments for and against wide spacing, and individual situations will differ.

Plant containers can be placed close together to increase the number of plants in an area. However, if plants are closely spaced, they compete for light and may grow tall and spindly rather than filling out adequately. Taller plants may create shaded areas and stop water from getting to smaller plants. Liquid feeding may not reach the lower plants. On the other hand, taller plants may provide some protection from the elements for smaller plants.

Some product types are more suited to close spacing than others. For example, tubestock grown for revegetation projects is frequently planted out at a young age; there is less requirement for the crowns of individual plants to fill out than for plants grown to a semi-advanced stage for strictly ornamental purposes. Greater uniformity of growth, improved product appearance and improved general health in semi-advanced stock can be achieved by greater spacing. These benefits must be balanced against the increased space required. In hot humid climates, wider spacing may be essential to ensure adequate ventilation (air movement), since this reduces the risk of disease outbreaks.

Pruning and training

The main purpose of pruning plants at the growing-on stage is to develop a neat, compact and bushy shape. All varieties in a particular batch are pruned in the same way, ensuring the plants have a uniform appearance at the time of sale. Other reasons for pruning at the growing-on stage are:

- to remove diseased or dead foliage and stems;
- to remove circling roots;
- to control the size of the plant;
- to train the plant into a specialised shape;
- to promote a uniform appearance among plants destined to be sold as a single batch.

Foliage pruning

At the growing-on stage, pruning is generally restricted to pinching back strong terminal shoots and/or giving the plant an overall light clipping. Removing the terminal buds forces the side shoots to grow, giving the plant an attractive dense shape. It also encourages stem thickening, which ensures sturdy growth when the plant is grown-on and planted in the landscape.

Root pruning

Root pruning has a similar effect to pruning foliage, in that it reduces vegetative growth. Severe root pruning impairs nutrient and water uptake, resulting in stunted growth. In the case of training plants as bonsai specimens, this is a desirable effect. In other plants, root pruning is usually only carried out to remove broken, diseased, tangled or circling roots when the plant is potted-on into a larger container or planted into the ground.

Training plants for specialised growth

Plants which are grown into specialised shapes and forms such as topiary, bonsai and hedges need to be trained from a very early stage.

Container-grown topiary plants are a useful way of value-adding to certain plant varieties, including buxus, lavender, azaleas, cupressus and ficus. Topiary is typically created by training one or more plants over a wire frame. As the plant grows, branches are clipped to the required shape or twisted or tied onto the frame. The most popular topiary shape for container plants is a 'standard', which is characterised by a single straight stem crowned by a clipped ball of foliage. Side growth is removed so that a single stem is formed, usually supported by a stake. When the desired branching height is reached, lateral growth is encouraged and frequently trimmed to stimulate bushyness.

Container-grown standards are also developed by grafting a spreading or prostrate variety onto a compatible upright variety; for example, an upright 'weeping grevillea' can be obtained by grafting the groundcover *Grevillea* 'Royal Mantle' onto *Grevillea robusta* rootstock grown to a height of 1.5–2 m (5–6.5').

Pruning tools

Use good-quality sharp secateurs to maintain a clean cut. Dip the blades in disinfectant to prevent the spread of diseases.

Staking

Plant growth can, in many instances, be controlled by staking. Creepers and climbers need to be staked for control. In general, staking young trees tends to promote growth in the top, to the detriment of the lower parts. Staked trees generally grow taller, but produce trunks which have a smaller diameter and less taper. If young trees are staked for too long (several years), the strength of the trunk and its ability to support a heavy crown can suffer.

Growing-on areas for container plants

These should be relatively level (no more than a 1:200 slope) for ease of access and handling and display of plants, but well-drained with a clean surface (preferably dry) below the plants. Concrete and asphalt are ideal. A thick layer of 1–2 cm (0.5–1") diameter crushed rock is also good, provided the soil below the layer can drain adequately. Pathogenic organisms can build up in old gravel surfaces, so frequent disinfection may be necessary and nursery hygiene practices, such as removal of diseased plant tissues, becomes increasingly important.

Woodshavings or other organic mulches are cheap and can be acceptable with many (not all) types of plants, but they are not the ideal surface. In many cases the roots of container plants will grow down into the organic mulches, making the containers difficult to lift. The organic mulches may harbour pathogenic organisms, or draw down nitrogen from the media in the containers as the mulch decomposes. Organic mulches can also require frequent replacement to counteract the effects of decomposition.

Raised benches are frequently used in growing-on areas. These have the advantages of being easier to maintain, allowing greater control of disease and root systems. Pots on benches can, however, be prone to excessive drying.

In-ground production

In-ground nursery production is the growing of plants in the ground, as opposed to growing them in pots. In-ground production is a specialised form of nursery production and may involve special equipment and machinery such as tractor-mounted tree-spades and trucks with cranes. Staff operating in-ground nursery production systems may require specialised training.

In-ground production has a number of advantages, including more consistent soil temperatures year-round, less-frequent irrigation requirements and no problem of pots being blown over. In-ground production frequently requires a longer growing period (sometimes five or more years) and a larger area of suitable land, but can result in a product that is suitable for immediate inclusion in large landscaping projects.

A wide variety of plants are grown in-ground. They include trees of various kinds, palms and ornamental shrubs. Turf farms also use in-ground production techniques.

In-ground production cycle

There are generally four phases to the production of in-ground nursery stock. These follow the same process as stages of production encountered in nursery plant production generally, although there are some differences due to the changes in growing techniques.

The four phases of in-ground production are:

1. selection of propagation material such as seeds, cuttings or tissue-culture plantlets;
2. propagation and care of nursery stock in the first year. During this phase of production, plants are maintained in a nursery bed. The aim of this phase is to develop strong, branched root systems. This phase of production is sometimes completed in pots, rather than nursery beds. Plants are sometimes sold at the conclusion of this phase as bare-rooted seedlings. This phase can be considered equivalent to the propagation stage;
3. growth into a sapling ('whip'). Following completion of the second phase, young plants are transplanted to a growing bed and trained to improve desirable characteristics such as a tall trunk with minimal branching. This phase can be considered equivalent to the transplanting and growing-on stages;
4. the 'whip' is frequently transplanted again to produce the finished tree. Following this transplanting, trees are often grown-on for three to five years, depending on the type of tree and required size of the finished product. This phase can be considered equivalent to the growing-on and marketing stages.

(University of Georgia, College of Agricultural and Environmental Science website)

Soil

A critical factor when producing in-ground plants is the health of the soil being used. Adequate soil resources are essential for in-ground production, and assessment of the soil should be a very high priority for those considering beginning an in-ground nursery system.

Soil organic matter

Organic matter is very important in improving and maintaining soils for the following reasons:

- it promotes the formation of a crumbly soil structure;
- it provides a source of nutrients for plant and animal growth;
- it acts as a buffer against extremes of temperature or chemical changes in the soil;
- it improves soil moisture retention.

The average mineral soil contains 2–5% organic matter. It is often difficult to increase the percentage of organic matter in a soil, but it is important to try to maintain that percentage. Organic content will drop if you remove plant material which grows in a soil (such as grass, crops or other plant materials) and don't return an equivalent amount of organic material. Organic matter can be incorporated into the soil in the following ways:

- when production is finished, the roots of plants should be cultivated back into the soil;
- compost should be added regularly;
- using organic mulches on the soil;
- feeding plants with well-rotted manure.
- green manure crops cultivated into the soil, or slashed/mulched onto the soil surface;
- using liquid organic fertilisers to stimulate biological activity.

Soil drainage

This is a measure of how quickly water infiltrates a particular growing media. Drainage can be tested simply by observing the way in which water moves through soil which is placed in a pot and watered. However, when soil is disturbed by digging, its characteristics may change.

For a more reliable result, use an empty can with the top and bottom removed. This forms a parallel-sided tube which can be pushed into the soil to remove a relatively undisturbed soil sample. Be careful not to rock the can from side to side as you lift it from the soil, as this will create a gap between the soil sample and the sides of the can. If you can remove the soil surrounding the can and carefully slide a sharp flat blade or similar object under the can, you will be able to minimise disturbance of the soil in the can. Leave a little room at the top of the can to hold water, add some to see how it drains then saturate the soil and add some more water to the top. You will often note slower drainage once the soil has become saturated.

Observations can also be made in the field after rainfall or irrigation has occurred. Simply take note of how quickly water infiltrates the soil, how much surface runoff occurs, and any places (depressions) where water sits for any length of time.

Soil pH

This is a measure of the number of hydrogen (H+) ions present in a particular media (soils or potting media). These H+ ions are mainly caused by aluminium from soil colloids reacting with water to produce free hydrogen ions and hydroxyl (OH-) aluminium compounds. The pH of a soil is measured using a logarithmic scale from 1 to 14, with 7 being neutral, above 7 considered alkaline, and below 7, acid. A one-unit pH change means a ten-fold change in the acidity or alkalinity of the media; for example a soil with a ph of 4 is ten times more acidic than one with a pH of 5, and a hundred times more acidic than a soil with a pH of 6. For most soils, the pH can range from 3.8 to 8.2, depending on the cations present. The pH of a growing media will affect the amounts of nutrients available for plant growth.

Plant species differ in the pH range they can tolerate. Most plants prefer a pH in the range 5.5–7.5, where most nutrient elements are available for plant growth. Outside this range some elements, such as phosphorus, may become insoluble ('locked') in the soil and unavailable to plants; others, such as aluminium and manganese, become so soluble that they are toxic to plant growth. In very acid soils, various agricultural chemicals (herbicides and nematicides) are not effective. The activities of the following soil organisms are also reduced: nitrogen-fixing bacteria, bacteria that convert ammonium to nitrate, and organisms that break down organic matter.

Reasons for soil acidity are:

- leaching – percolating water removes nutrient elements that are replaced by hydrogen and aluminium;
- crops removing nutrients;
- acid-forming fertilisers are used (e.g. superphosphate, ammonium sulphate);
- organic matter breakdown, releasing hydrogen ions;
- acids are produced by growing roots.

Testing pH

Soil pH can be simply measured using either liquids or papers (litmus) that change colour according to the pH of the media being tested. It can also be measured using electronic meters. These will be more expensive to purchase than indicator liquids or papers, but they are cheap to run, quick and easy to use and, depending on the type purchased, give very accurate results.

Plant nutrition

More than fifty elements are used by plants, in varying amounts. At least sixteen elements are used by all plants. The nine nutrient elements generally used by plants in the largest quantities are carbon (C), hydrogen (H) and oxygen (O), which are obtained from air and water; and nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S), which are derived principally from the soil or growing media. These are sometimes known as the major elements. Nitrogen, phosphorus and potassium are the elements most widely used in fertilisers.

Carbon, hydrogen and oxygen are readily obtained from air and water, while calcium, magnesium and sulfur are generally present in sufficient quantities in soils to maintain good plant growth.

The remaining elements are known as micronutrients, or trace elements. They are just as necessary for plant growth as the major elements, but in much smaller quantities. Examples are copper (Cu), molybdenum (Mo), cobalt (Co), zinc (Zn), manganese (Mn), iron (Fe) and boron (B). Some soils, particularly well-leached ones, may be deficient in one or more trace elements. Often one application of a fertiliser containing the required trace element is sufficient to ensure adequate supplies of that nutrient for years.

Soil nutrition is to some extent indicated by the vigour of plants growing in a soil. Simple soil test kits can also be used to give approximate levels of nitrogen, potassium and phosphorus. More comprehensive and accurate soil analysis can be carried out by soil laboratory services.

Improving soils

There are many ways to improve soils. These include:

- adding sand to clayey soils to improve drainage. This usually requires substantial amounts of sand, well-mixed, to have the desired effect;
- adding clay to sandy soil to improve its ability to hold water;
- adding organic matter to any but very organic soils. While improving water-holding capacity, added organic matter does not affect drainage to the same degree that adding clay does;
- adding organic matter usually improves the nutritional status of the soil;
- using soil ameliorants. Lime can help to reduce acidity and improve soil structure. Gypsum can help improve soil structure of clayish soils. Wetting agents help water penetration in sandy and highly organic soils;
- rotating crops. Growing the same plant year in, year out can exhaust certain nutrients, and allow diseases that affect that plant to remain in the soil;
- using good cultivation techniques;
- growing legumes as a cover crop to help fix nitrogen into the soil. These can also be green-manured, or dug back into the soil to increase the soil organic matter content;
- surface-working the soil (mounding, ridging, laser grading, terracing) to improve surface drainage or reduce erosion.

Testing soils

There are many sophisticated tests to determine the chemical and physical characteristics of soils. Generally these tests require very expensive laboratory facilities beyond the means of the average working horticulturist. There are, however, laboratories in most major cities which will take soil samples and, for a fee, conduct the tests.

Soil sampling procedures

- Take samples from soil mix stockpiles before adding fertiliser.
- Take samples from soil in beds prior to seeding or planting.
- Take samples from soils in pots, from the top and bottom of several different pots.
- Use a soil auger, corer or similar device for taking samples to ensure a sample across the total profile of the soil. The soil sample to be analysed should be representative of the area.
- Wait at least six hours after watering (or rain) before taking a sample.
- If dry fertiliser has been used, wait at least five days after application before sampling.
- If liquid fertiliser has been used, wait at least two days before sampling.
- Remove mulch from surface and the top 1 cm (0.5") before sampling.

Using a conductivity meter

This is a small electronic device that measures the flow of electricity through water, potting media or soil. When mineral ions are present (e.g. nutrients from fertilisers) electric currents will flow faster. The more mineral ions present, the faster the electric current. The meter will then give a higher reading.

By testing soil or media regularly it is easy to determine if there are too many toxins present, whether salt residues from fertilisers are too high, or whether fertiliser levels are too low and a plant needs feeding. Conductivity meters are also useful for keeping a check on water quality. They are relatively inexpensive, and can be an extremely useful tool if used frequently and correctly.

Toxins

Toxins that will seriously damage plant growth can occur through the build-up of excess salts in growing media, from overuse or build-up of chemicals such as pesticides, and from chemicals found in raw (uncomposted) woodchips or shavings used for growing media, particularly those of *Pinus* and *Eucalyptus* species. A simple 'radish test' can often show whether a growing media is safe to use.

1. Place the mix in a pot.
2. Sow several radish seeds.
3. When the radish seeds reach the developed two-leaf stage, carefully remove some seedlings and wash the mix from the roots.
4. If the extreme tip of the root is a dark colour, there are likely to be toxins in the mix. If not, the mix is likely to be free of toxins.

5

Selecting and managing nursery stock

Consider your stock options

Regardless of the type of nursery, one of the most important decisions is what type of plants should be stocked.

The first decision is whether to specialise. A nursery can specialise in terms of the plant species grown, or the size of plants grown. Some nurseries grow a wide variety of plants but only in one size container, or perhaps only in the open ground (where they are dug up and balled or potted before selling). Other nurseries might concentrate on a particular group of plants such as herbs or natives, but grow and sell those plants in a variety of sizes and containers. Some growers choose to be even more specific, selling only one genus of plants, such as fuchsias, geraniums or carnations.

Figure 5.1: This small retail nursery caters to a local market and stocks plants suitable for growing in the immediate area.

There is a very real danger in choosing what to grow on a whim or a fancy. It is a bad business decision to specialise in a group of plants just because you like them! They may not be popular with customers or, if other nursery managers in the same locality like that plant as much as you do, supply of that type of plant is likely to exceed demand. Stock selection should be based on careful market research as well as assessment of what you as a nursery owner are capable of.

Developing a stocklist should be an ongoing task. Plant varieties should continually be added to and removed from your stocklist. The numbers grown or stocked should also be added to and reduced regularly. Each year, an assessment should be made of what has sold, what has not sold, and what has been requested or ordered. This assessment should form the basis of modifications to stock range and quantities.

If you are new to the industry you may need to experiment to find your niche. Remember that fashionable plants that you read about in magazines and see everywhere are sometimes being grown or sold by every other new nurseryman, so there might be a lot of competition. It is also important to remember that many of the newer varieties being sold widely are protected by plant breeders' rights, so it is illegal to sell them unless you have an agreement/licence with the rights-holder to do so.

Retail nurseries and garden centres

Retail nurseries may cater to either a local or regional market. Small nurseries generally cater to a local area. When the local market is a newly developing urban area, these nurseries will normally sell large numbers of fast-growing trees and shrubs. There will usually be demand for all types of plants, so the nursery should stock a wide variety. The exception is where housing in the area is based on a particular theme, or local government planning controls restrict development with the object of maintaining indigenous plants or restricting particular types of plants.

In some countries or localities a certain style of garden might be more popular, so plants for that type of garden will be in greater demand. In built-up areas with smaller properties or flats and units, smaller plants will probably be more in demand. Indoor plants, hanging baskets and container plants will probably be in greater demand in densely populated areas than in rural areas.

After an area is established, the local nursery will make more sales of plants needed to maintain or renovate established gardens. Smaller ornamental and flowering plants, groundcovers and annual seedlings can become an important stock item. Anyone establishing or taking over a local retail nursery should visit similar sized nurseries in similar localities to see the mix of plant varieties being stocked.

Larger retail nurseries can cater to a regional market, attracting people from a wider field. If located in a prominent position such as a main road, or promoted in an appropriate way, this type of nursery can draw all types of customers wanting nearly any type of plant. Specialist sections can be incorporated into the nursery, and those sections promoted to a specific market; for example, an orchid section selling and displaying a wide range of orchids might be promoted widely among orchid enthusiasts to attract them to the nursery.

Wholesale nurseries

Wholesale nurseries, and sometimes wholesale/retail nurseries, often specialise in a particular group of plants. The following are common types of specialisations: trees, shrubs and groundcovers, flower and vegetable seedlings, natives, ferns, conifers, herbs, indoor plants, fruit trees, orchids, water plants, perennials and rock plants, palms, rainforest plants, or budded and grafted plants.

Specialist nurseries

Most regions or countries have small numbers of more highly specialised nurseries. These nurseries often service a whole country, or even an international market. The market is rarely big enough in even a large city to sustain this type of specialist nursery without marketing its plants more widely.

Figure 5.2: This large production nursery specialises in impatiens. Nurseries like this will onsell plants to customers even a long distance away.

Figure 5.3: Impatiens is a fast-growing plant that is easy to propagate, hence the price of the final product can be kept down.

A specialist nursery often sells plants both retail and wholesale, or wholesale only. It might deal with only one genus (or mainly one genus). Nurseries of this type might specialise in one of the following plant groups: roses, bonsai, fuchsias, proteas, azaleas and rhododendrons, chrysanthemums, daisies, liliums, iris, cacti, pelargoniums, impatiens, african violets or camellias.

Some nurseries combine a number of different but compatible specialist types of plants, in that way buffering against any problems such as an unforeseen drop in demand for one of the types they grow. Examples of combinations include:

- azaleas, rhododendrons and camellias;
- ferns and orchids;
- herbs and perennials;
- deciduous fruit and ornamental trees;
- bulbs and perennials;
- proteas and banksias.

To remain competitive, specialist nurseries should be prepared to evolve. This means altering specialisation as trends and demands change.

Criteria for selecting plants

Below are criteria that can help you decide which plants and plant varieties to grow or stock in your nursery.

Ease of propagation

Is it an easy, moderate or difficult plant to propagate? Very easily propagated plants may bring a lower wholesale price, and their supply in the marketplace might be greater. Difficult plants may be more costly to produce, and more risky to rely on unless you have above-average skills.

Availability of stock

Can it always be purchased in the form you want (i.e. is seed or tubestock of the plant available for purchase)? If the propagation material is imported, you will need to consider quarantine restrictions.

Growing time

Some plants can be ready to sell within months, others take many years. Plants that can be produced and sold quickly will generate income quickly.

Suitability to your facilities

Do you have the right buildings, propagation equipment and other facilities to grow the plants under consideration? Do you have the money and space to provide those facilities?

Suitability of climate

What plants are most suitable to grow in your climate? It is always more efficient to work with the environment rather than trying to modify it.

Distance from potential markets

What will it cost in time and money to transport the plants? Transport is costly, and can be risky.

Staff skills

Can I and my staff successfully grow and manage these plants? Don't try to do what you and your staff are not skilled to do. Someone with more experience or specialist skills will probably do it better and cheaper.

PRACTICAL EXERCISE
DEVELOPING A NURSERY STOCKLIST

There are many different ways of developing a nursery stocklist. The following method is just one example. Use the stocklist worksheet on page 65 to assist you.

1 Decide the big questions first.

a) How will plants be sold?
- wholesale
- retail
- wholesale and retail
- mail order.

b) How will plants be sold and in what size?
- cuttings/seedlings
- tubestock
- small
- standard or medium pots
- advanced containers
- bare-rooted
- balled (dug up from ground and a ball of soil wrapped)
- other.

c) What quantity of plants will be sold annually (production aim)?
- gross quantity
- quantity of each variety
- gross financial value
- financial value of each variety.

d) Which types of plants will be sold and what percentage of nursery turnover will be devoted to each group?
- native plants
- indoor plants
- seedlings
- deciduous trees
- herbs
- general trees and shrubs

- perennials
- cacti and succulents
- orchids
- rhododendrons/azaleas/camellias
- ferns
- roses
- other.

2 Visit different nurseries which sell the types of plants you plan to stock. Compile a list of the plant varieties sold by these nurseries. These are often likely to be the more saleable varieties, though you may also find clues to other potential varieties and unfilled niches.
3 Look through gardening magazines, nursery catalogues, trade journals etc. to determine which varieties on your list are mentioned most, and whether any other varieties of plants seem to occur frequently in the literature.
4 Consider the marketability of your selected plants. Some are far superior as ‘turnover plants’ than others. Group the plants according to criteria, such as:
   - very highly marketable (VHM) – traditionally and currently these plants have sold very well at most times of the year;
   - highly marketable (HM) – sell very well but only at certain times of the year;
   - good standard line (GSL) provided you do not grow too many;
   - usually sells well (USW) provided the quality is good. We suggest you limit such varieties to not more than 2% of your total production;
   - requires some effort (RSE) to sell, but normally a reasonable line provided quality is good and quantity is not too high. We suggest that you should limit this line to not more than 0.25% of your total production;
   - often a poor seller (PS);
   - high-risk variety (HR) – these plants may do very well or very poorly. They should be treated as a speculative crop.

When considering the marketability of a plant, you should take into account all the following aspects. Consider the normal and acceptable way to sell the variety in question. Sometimes you can do better selling it in a different way from what is ‘normal’, but the customers may be preconditioned to buying particular varieties in particular pot sizes, at a certain time of year and looking a certain way. The following system or something similar can be used to plan the way each plant on your stocklist can be presented to the market.

Packaging

- 50 mm tube
- 100 mm plastic pot
- 125 mm plastic pot
- 125–150 mm plastic pot
- Pun – punnets
- Bare – bare-rooted
- Bal – balled
- Bsk – basket plant

Presentation

- Fl – sell when in flower only
- Pic – pictorial label is very important
- Il – inexpensive label, only correct naming is really important
- St – normally sold tied to a stake
- Trel – normally sold tied to a trellis

Marketing time

- Sum/Win/Aut/Spr – indicates the months when the plant is released in retail outlets.

Compare the different varieties, and determine the quantities which you should aim to stock or sell. Delete from the list any plants which you are more uncertain about (in terms of your ability to produce, obtain them or sell them). The final list should be viewed as a general guide for either obtaining stock for a retail nursery, or growing plants in a wholesale nursery. It should be adapted to changing conditions in the marketplace.

PRACTICAL EXERCISE
NURSERY STOCKLIST WORKSHEET

Following the procedure outlined above, fill in the following worksheet to develop a nursery stocklist. Owners of this book are given permission to duplicate this worksheet as many times as necessary to accommodate their needs.

Stocklist for plant type

Plant variety	Marketability	Packaging	Presentation	Marketing time	Annual stock numbers

Example stocklist for plant type: trees

Plant variety	Marketability	Packaging	Presentation	Marketing time	Annual stock numbers
Acacia baileyana	VHM	Tube	II	Aut/Win	2000
Betula alba	HM	Bare	Pic	Win	750
Cedrus atlantica glauca	GS	Bal	Pic	Win/Spr	400

Managing plants

Once a basic stocklist has been established it is essential that the nursery keeps track of stock. A good nursery manager will know the numbers of each type of plant bought or propagated, the numbers lost through death or being thrown out, and the numbers sold. Nurseries are increasingly able to use modern technology such as barcoding and computers to record this type of information.

Initially it will take a considerable effort to compile a stocklist, but it should be done before investing any major amounts of money in either purchasing or growing plants. It can make a significant difference in your management of the nursery.

Then, you need to figure out how to manage those plants. A significant part of nursery work is simply keeping plants alive and healthy. The biggest and healthiest plants are inevitably the ones customers prefer to buy. Healthy plants will also reach a saleable size a lot quicker than those which are stressed by pest or disease problems, inadequate watering or poor nutrition. It costs a lot of money to look after plants in a nursery. They need to be fertilised, watered, sprayed, moved about, pruned, potted-up, dug up, transplanted and so on and each step requires labour and product inputs.

Figure 5.4: These *Anigozanthus* sp. are showing signs of infection by inkspot fungus. It is critical to inspect plants regularly and remove or treat infected stock.

Stock plants for production/propagation nurseries

Propagation nurseries must have a reliable supply of good-quality plant material. This might be seed from reliable seed suppliers or from plants which can be readily used as a source for seed collecting. It might also be cutting or grafting material from healthy, correctly identified plants ('known varieties').

Plants used as a source of propagating material are called 'stock plants'. Stock plants might or might not be on the nursery site, but ideally they should be in a convenient and accessible location. They are extremely important to the operation of a nursery, and establishing a reliable source of stock plants is one of the nursery manager's biggest problems.

The quality of stock plants is perhaps the biggest influence on everything which happens later in a nursery. If stock plants are in poor condition:

- cuttings or grafts may have a lower rate of success;
- cuttings may be slower to form roots, and grafts slower to grow together;
- pest or disease problems can be transmitted from stock plants to other plants in your propagation area or greenhouse;
- new plants might not develop as well as those taken from healthy, vigorous stock.

Selecting stock plants

When selecting stock plants, use only:

- plants free of disease and pests;
- plants which are true to type;
- plants which have been grown under preferred conditions;
- plants which have been growing well;
- plants which have been adequately fed, and are free from signs of any nutrient deficiency or leaf burn.

Clonal selection, practised in some countries, involves careful selection of one plant of optimum quality and type. All stock plants are then propagated from this one parent plant. It is essential that your original stock plants come from a very reliable source. Don't assume that their label is correct, and don't assume that a property owner knows the correct name of the plants on their property. There are many incorrectly labelled plants in gardens and nurseries.

Correct labelling of stock plants

Incorrectly labelled plants are a major problem in many nurseries. If a customer is paying for a particular variety of plant, they should be certain of getting it. Selection of a 'true-to-type' cultivar is something which often requires expert knowledge. If there is the slightest doubt about the identity of any stock plant, don't propagate from it until it has been identified by an expert, such as a botanist experienced in plant taxonomy. Many botanical gardens or herbariums will readily identify plants for you. Some will do it for free, others may charge a small fee. Cross-check spelling with a reputable publication such as the *Royal Horticultural Society Dictionary* or *Hortus Third*. If in doubt, contact a herbarium (usually attached to botanic gardens) to double-check the spelling. Do not assume that a label supplier has the correct spelling, as this is not always the case.

Make sure that any labels used are durable, and that information is clear and easy to read. It is a good idea to keep a record book or map in a secure place that includes as much detail as possible about each stock plant. Details recorded can include the original source of the plant, who identified it, maintenance details, and when and how much cutting material is taken. This provides a good back-up in case of lost or damaged labels, and if doubts are raised about the identity of propagated plants.

Planting out stock plants

Stock plants should always be planted and maintained in the very best conditions. Factors such as aspect, amount of light received and soil conditions should be carefully considered. Any stock plant area should be cleaned thoroughly before planting. Ideally, the soil should be sterilised. All weeds and rubbish must be removed from the area. Stock plants should be kept apart from the nursery's main production, so that disease or pest problems in the nursery can be stopped before they infect the stock area.

Treatment of stock plants throughout the year

Pruning may be necessary to control the type of growth as well as the size and shape of the plant. Pruning a few months prior to taking cuttings can stimulate more growth of the type which is best suited for cuttings. Feeding should be adequate, but be careful – too much nitrogen can stimulate too much soft growth. Irrigation is particularly important during the growing season. Some types of plants, such as those grown from hardwood cuttings, may require very hard annual pruning to encourage the development of suitable cutting material for the next season.

Sources of stock plants

It is nearly always best to grow stock plants on the nursery site. They are immediately accessible, maintenance can be easily controlled, and cutting material can be taken when it best suits the nursery's requirements. Sometimes, however, there isn't sufficient room at the nursery, or the growing environment is just not as good as elsewhere. When grown on the nursery site, avoid giving the stock plants second-rate positions. They should never be grown in places which are 'no good for anything else'.

Some nurseries grow their stock plants in rows in a separate field. The plants are well-fertilised, well-watered and given the best care in every possible way. Other nurseries grow stock plants in large containers in premium potting media and, again, the plants are given special care.

Nursery plants are also frequently used to supply propagation material (plants which are to be sold are pruned to supply cuttings). This can supply a significant amount of material in some cases, but pruning must be careful and controlled so as not to destroy the shape or general health of plants which are destined for market.

Permission can sometimes be obtained to collect from public gardens (botanic gardens), parks, commercial properties and road plantings. It may be necessary to offer something in return – perhaps exchanging some free plants for the privilege. Private gardens can also be a source of material, but the difficulty is often discovering what exists close to the nursery. By joining local garden clubs, a nursery manager can sometimes establish a source of propagation material and at the same time develop local goodwill for the nursery. Native plants can sometimes be collected from public natural areas, but there are legal restrictions on what you are allowed to do. These should be checked out fully before collecting *any* propagating material.

If collecting from properties not owned by the nursery, it is important not to abuse the privilege and risk not being able to collect in future. Be polite and friendly to owners, employees or caretakers of properties you collect from and their cooperation in the future will be invaluable.

Propagation material

It is essential to keep propagating material as fresh and healthy as possible between the time you collect it and when it is used. The best way to do this is to collect it immediately before you use it. Dormant vegetation (e.g. sticks from deciduous trees collected after the leaves fall) will be very slow to deteriorate, but some material can deteriorate within a matter of hours (e.g. seeds or cuttings from some lush rainforest plants).

Cutting or grafting material collected for propagation is generally best placed in a plastic bag, perhaps with a little moist sphagnum moss, and put in a cool place such as an insulated box or car fridge, until it is to be used. Sometimes material is collected, stood in buckets of water and placed in a cool area such as under a bench. Material that will not be used immediately can often be stored in the shelves of a refrigerator (not the freezer section) for a week, sometimes longer, before being used.

Sources of seed

Nurseries can generally grow plants more easily and cheaply from seed than by any other technique. Plants grown from seed, however, often vary considerably in characteristics; for example, some might grow stronger or taller than others, be more susceptible to disease, or have different colour flowers. Nevertheless, a wide range of plants are grown by seed including most bedding plants (e.g. annual flowers), vegetables, farm and forestry trees and many rootstocks for fruit and deciduous ornamental trees. The problems of seedling variation can be minimised by paying particular attention to the source of seed, and how the seed is treated both in storage and in the propagation process.

Four main sources of seed

1. **Seed collected from the wild** – Seed collected from plants growing in their natural habitat is less likely to be cross-pollinated by plants from other gene pools/provenances, and you can be more certain of where it came from and how it will grow than if you had purchased it from a seed supplier.
2. **Seed exchanges** – Many botanic gardens operate seed exchange programs, where they produce annual seed lists and swap seed with others involved in the program. Such programs are particularly valuable as a source of scarce varieties. Some associations and societies, such as the Society for Growing Australian Plants, also operate seed banks for their members.

3 **Commercial seed suppliers** – There are thousands of seed companies operating throughout the world. Some breed new varieties of plants and grow seed crops to harvest. Others buy seed from collectors (who collect from the wild or from gardens). Major problems of using this source include:
- collectors identifying seed source plants incorrectly;
- unreliable supply (if they can't supply, it's too late for you to collect for yourself);
- uncertainty about quality;
- developing a dependence on the supplier.

Major advantages of using this source include:
- convenience;
- obtaining a seed source for plants which do not set seed well locally;
- saving labour costs.

4 **Collecting seed yourself locally** – You or your representative might collect seed from plants on your own or on other nearby properties as it matures throughout the year. Seed may sometimes be collected from public parks and gardens or private gardens (with permission). The major advantages of this source are:
- you have a great deal of control over collection, storage and treatment;
- you can be sure you have got exactly what you want;
- you learn a lot more about the plants you are growing, because you see them in their mature state;
- you can save on the cost of purchasing seed (but collecting can be time-consuming, particularly if you have to travel to collection sites).

Major disadvantages are that the amount of seed available to harvest may vary considerably from year to year, and you are tied to the time when the seed is ready to harvest. This means that you may have to stop other tasks while you go and collect seeds. This can often be very inconvenient.

Seed quality and provenance

The source of seed is very important with regard to quality. Some seed suppliers do not supply pure seed. Rubbish or weed seeds may be mixed with the seed, or the seed may be infested with pests and/or diseases.

The time of seed harvesting and the health of the parent stock are also important factors. The percentage viability of the batch may be reduced if seeds are collected before they have properly matured, and the vigour of seedlings may be low if the seeds were not collected from strong and healthy plants.

Gene provenance of the parent plant can affect the performance and growth characteristics of seedlings. The place of origin of a particular plant gives it a range of characteristics which are very specific to that population and thus that batch of seeds. For example, *Eucalyptus camaldulensis* seed from one stand of trees might be very tolerant of salt, while seed from another stand of *Eucalyptus camaldulensis* might not tolerate salt at all. This characteristic is known as the seed's 'provenance'.

Storing seed

Seeds are alive and like any living thing they can be harmed by adverse conditions. Seeds of some species do not store for very long at all; in these cases, propagation should be done with fresh seed only (this group includes many spring-ripening seeds of temperate zone plants). Most seeds will store for at least six months without loss of viability, provided the environmental conditions of their storage are right.

Stored seed can be affected by:

- moisture content. Many short-lived seeds lose viability if they become dry – citrus seed, for example, can withstand only slight drying. Medium- to long-lived seeds need to be dry to survive long periods of storage (4–6% moisture level is ideal – higher or lower can be detrimental to viability). For seeds not adversely affected by low moisture, each 1% decrease in seed moisture, between 5% and 14%, doubles the life of the seed. Fluctuations in moisture levels during storage will reduce longevity. For this reason, seeds keep better in dry climates than in areas of high humidity;
- temperature. Most seeds will store for longer periods at lower temperatures. Each decrease of 4.6°C (9°F) between 0° and 44°C (32° and 112°F) will double the seed storage life;
- storage atmosphere. Some techniques of modifying gas levels (increasing carbon dioxide) can be of value.

Types of seed storage

1. **Open storage with no control** – Storage in bins, sacks or paper bags. Fumigation or insecticide/fungicide applications are sometimes necessary. Seeds of many annuals, perennials, vegetables and cereals can be successfully kept this way. Apart from a few exceptions (corn, onion, parsley, parsnip, delphinium, kochia, candytuft), seeds from these groups will normally retain viability for at least a few years.
2. **Cold storage with or without humidity control** – Temperatures below 10°C (50°F) will improve the longevity of virtually any type of seed. Cold storage of tree and shrub seed is recommended if the seed is to be held for more than one year.
3. **Cold moist storage** – Seed should be stored between 2° and 10°C (35–50°F) in a container which holds some moisture-retaining material, such as peat or sphagnum moss. Relative humidity should be 80–90%. Examples of species requiring this type of storage are *Acer saccharinum*, Carya, Castanea, Corylus, Citrus, Eriobytra (loquat), Fagus, Juglans, Litchi, Persea (avocado) and Quercus.

Quarantine issues when selecting stock

Many plants are sourced from overseas growers, and this can be an excellent way for a nursery to introduce new varieties to the market. However, strict regulations apply to the import of seeds and plant material from overseas. In the past, deliberate introductions of ornamental plants from overseas resulted in environmental catastrophes, including weed invasions, altered natural ecosystems and the spread of exotic, detrimental pests and diseases. Quarantine laws are designed to prevent similar problems occurring in the future.

Most countries are aware of the problems caused by the unrestricted movement of plant material within and between countries and, on an international basis, quarantine standards are becoming increasingly stringent. Certain protocols must be observed – always contact the quarantine authority in your own country and the country from which you wish to import the plants. The information is readily available on the internet and from government quarantine authorities.

Before bringing a new plant into the country, you must find out whether it has been cleared for importation into the country. Any plant deemed a weed risk will be denied for import. Endangered species protected by the Convention for International Trade in Endangered Species (CITES) may also be restricted for importation. If the plant has not been cleared, the quarantine authority may undertake an assessment, which can take some time as field and greenhouse trials may need to be carried out to evaluate its weed potential.

If the plant is currently permitted for entry, an import permit can be obtained from the quarantine authority. The permit will specify conditions and requirements that must be met, such as pre- and post-dispatch treatments like methyl bromide fumigation. Once plants arrive in the country, they are inspected by quarantine officers, treated and quarantined for a period of time at a registered quarantine station.

Choosing, treating and shipping stock overseas

- Select only healthy plants that are free of obvious diseases.
- Select plants with hardened growth rather than soft new foliage.
- Ship perennial plants when they have died down.
- Ship deciduous plants just before they emerge from dormancy.
- Remove all traces of soil from the roots prior to shipping, otherwise the plant may be denied entry or will have to be cleaned by the quarantine authority. Sphagnum peat and perlite mixes are acceptable alternative media for imported/exported plants.
- Use new cartons. Ensure there is no free water in the package.
- Pack the bundles loosely and cover with protective packaging such as polystyrene to minimise bruising.
- Attach a copy of the import permit and other relevant shipping and invoice documents to the outside of the parcel.

Environmental weeds and plant selection

Invasive plants are a very real threat in modern society. They have dramatic environmental effects such as causing extinctions of native plants through competition, affecting populations of animals ranging from micro-fauna and insects up to fish, bird and game animals, and even altering watercourses and landscape functions. They can also be toxic to domestic animals such as cattle. Invasive plants impose a significant financial cost on human populations. A large proportion of invasive plants have been spread and introduced to new areas through the amenity horticulture trade.

Nursery managers have a particular responsibility to consider the potential environmental impacts of plants they stock. In addition to the direct environmental impact, it is the responsibility of every commercial nursery operator to maintain a good name for the nursery industry. In today's world of increasing environmental consciousness, it does not do a business any good to be seen as contributing to the damage of natural areas.

Some factors, such as heavy seedset, high seed viability or longevity, capacity for seed to travel long distances (via wind or birds, for example) or a high capacity for vegetative reproduction, make particular plants more likely to become invasive than others. However, invasive species also vary from area to area. This is due to a number of factors, such as the presence or absence of pathogenic organisms in a particular locality, or the regional environmental conditions.

Nursery managers must be aware of the general characteristics of invasive weeds in the areas they sell to, and familiar with the weed species in these areas.

Small retail nurseries selling to a particular local area may find this task easier, since they will be dealing with a relatively narrow range of environmental conditions. These kinds of nurseries may also suffer difficulties sourcing particular plants and excluding others from larger wholesalers. Managers of small nurseries may also come into direct contact with the public, who may have complaints about invasive nursery plants or may want varieties that a nursery manager considers invasive. Thus, retail nursery managers have an important role in educating both the consumer public and the wholesale nursery sector in environmental weed issues.

Larger nurseries catering to regional supply may never come into direct contact with the impacts of invasive weeds. These nurseries may supply plants to areas where environmental conditions, and thus plant invasiveness, are significantly different from their own. Managers of larger nurseries have a responsibility to communicate with horticulturalists and other professionals in the regions they supply to in order to maintain appropriate stock selection.

The invasive potential of new commercial varieties should be thoroughly tested prior to commercial release. Each and every nursery manager should consider it their responsibility to ensure that they do not supply plants to areas where the plants will be invasive. Complementary to this responsibility is the nursery industry's role in promoting appropriate plants for particular areas. Appropriate plants include native and non-invasive varieties.

In many areas of the world, voluntary and regulated bans on particular plants are becoming common and some areas have established nursery accreditation schemes focusing on environmental weed issues. The Bushland-friendly Nursery Scheme in New South Wales, Australia, is one such example.

Managing plants in retail nurseries

A retail nursery needs to keep plants in peak condition at all times. Plants are often brought into a retail nursery from a different environment, sometimes following a long trip on a truck. These things stress the plant, and it is only natural for a plant to deteriorate a little when it is first brought into a retail situation. The deterioration may be mild and may take days or even weeks to become visible, depending on factors such as the type of plant and time of year. Nurseries with a high turnover do not have such a problem with plants deteriorating. For other retail nurseries, it can be a constant battle to keep the plants looking good.

Routine jobs should include:

- daily inspection of a selection of individual plants. Check for overwatering or underwatering, diseases, pests, leaf scorch, frost or wind damage and any other adverse symptoms;
- removing spent (dead) flowers;
- removing damaged or marked leaves;
- pruning to shape;
- moving overcrowded pots to allow better ventilation and light penetration;
- removing sick plants to an out-of-sight 'hospital area';
- rearranging plants to move the most attractive and healthiest plants, and those in flower, to a prominent position;
- moving out-of-season stock away from sales areas;
- moving seasonal stock into prominence;
- moving plants into protected areas when weather changes;
- potting-up potbound plants;
- routine fertilising;
- routine spraying for weeds, pests and diseases;
- maintaining good hygiene andcleanliness.

How to conduct a plant inspection

It is essential to respond **immediately** to problems detected during inspections. When a plant becomes sick, the cause could be one or more things. More often than not there are several factors involved; for example, minor diseases or environmental problems weaken the plant making it more susceptible to a more damaging (obvious) disorder. When you inspect a plant for problems, you need to systematically consider all possible factors.

First

Systematically examine the plant and take note of any abnormalities.

- Look at the leaves. Are there abnormal markings, swellings, distorted shapes etc.? Is there any discolouration? Are there dead patches or holes?
- Look at the fruit and flowers. Are the flowers and fruit developing well? Is there any fruit drop? Is fruit undersized?
- Look at the stems and branches. Are the growth tips lush and growing fast? A healthy plant will have lush growing tips. If other parts are damaged but the tips

are lush, this can indicate that the plant is recovering from a previous problem. Are there any abnormalities on the stems?
- Look at the roots. Are the root tips fresh and healthy or black and rotting? Are the roots strong or is the plant loose in the ground? Are roots coming out of the surface of the ground? This may indicate the mix is low in fertiliser, dry deep-down or eroded away, hence the roots are coming up for water and nutrients.
- Note which area is most affected. The parts which are most exposed to the problem will be most affected. Fruit rots may occur on branches close to the ground where disease spores can splash up from the soil. Small animals tend to eat lush growth in preference to older tough foliage, while grazing animals will eat lower growth on shrubs and trees that is within their reach.

Second
Examine the surroundings and note anything which may relate to abnormalities noticed when you examined the plant.

- Is the soil wet or dry? Is it well-drained?
- Are the surrounding plants healthy? Do they have similar symptoms?
- Consider environmental factors such as exposure to wind, frost and sun. Frost damage occurs more on parts most exposed to frost. Sunburn occurs more on parts exposed more to the sun, or on new soft growth. Has anything been changed since the problem arose, such as a building or large tree which provided protection being removed?
- Is the plant at the bottom of a hill or slope? Could something have washed down from further up the hill (weedicide, disease from another plant)?

Third
Based on the information collected, classify your problem. Is it mainly caused by pest, disease, nutrition, environment or weed? Decide whether there is likely to be more than one major problem. Eliminate any problem groups that you can.

Fourth
Select a suitable control method or methods.

If you are unsure

For any problem that you are uncertain about, devise a treatment which might be used and apply that treatment. The plant's response will help you determine whether you diagnosed the problem correctly, or whether it was something else. The following table may also give some clues to possible causes of plant disorders.

Table 5.1: Diagnosis of plant disorders

Symptom	Possible causes	Treatment
Spindly growth	Low light (e.g. shade), excess water, high temperatures, plants too close together	Improve light, cut watering, reduce night temperature in greenhouse by cooling/ventilation, reduce feeding, increase spacing between plants
Growth reduced	Insufficient nutrient and/or water	Feed more often but in low concentration. Water more often
Old or lower leaves yellowing	Nitrogen deficiency	Feed the plant with a fertiliser high in nitrogen. A highly soluble or liquid fertiliser will give quick results. This can be followed up with a slow-release nitrogen fertiliser or further applications of highly soluble forms
Young leaves yellowing between veins	Iron deficiency	Similar treatment to nitrogen deficiency
Purple leaves	Phosphorus deficiency	Similar treatment to nitrogen deficiency
Root tips burnt or discoloured on container-grown plants	Excess fertiliser, salts or toxic chemicals in soils or potting mixes (sometimes occurs when media is fresh)	Leach media thoroughly to wash away excess nutrient or toxin, or repot into potting mix with low salt/toxin levels
Woody growth	Plants overhardened (i.e. exposed to too tough conditions), or slow-growing	Increase feeding; if problem is excessive, also prune
Stems very wet and decaying at base of the plant	Damping-off disease caused by dirty conditions, high humidity and/or overcrowding	Thin out plants, apply fungicide
Algae, moss or liverwort on surface of soils and potting mixes	Excess moisture and nutrient on surface. Doesn't harm plant initially but can impair flow of nutrient solution in the long term	Reduce watering, increase ventilation, use better-draining medium. Some chemicals (ferrous sulphate) can be used to kill algae and moss
Poor root growth	Poor aeration or drainage in media, low temperature in media, toxic chemical in media	Determine which is the problem and act accordingly

PRACTICAL EXERCISE: NURSERY INSPECTION SHEET

It can be a useful exercise to develop a checklist or inspection sheet for nursery staff to use when undertaking routine inspections for pest and disease problems.

Most nurseries are divided into several sections (e.g. propagation area, shadehouse, greenhouse), and a separate inspection sheet should be filled out for each section. The following is an example. The nursery manager may decide to establish a procedure where this sheet is used daily or weekly to inspect the nursery to discover whether any pest, disease or other problems are developing and need attention. This can be an excellent time-saver for the manager, allowing a clear picture of the current status of the nursery to be determined quickly and efficiently.

NURSERY INSPECTION SHEET

Nursery name:

Inspection date:

Inspection carried out by:

Nursery section:

Overall condition of plants (generally)

- Very healthy
- Healthy
- Medium health
- Sick
- Very sick
- Dead

Condition of the worst plants (the worst plants that you are inspecting)

- Very healthy
- Healthy
- Medium health
- Sick
- Very sick
- Dead

Root inspection (generally)

Expose some of the roots on at least two different plants by digging into the soil or partly removing the plant from the pot.

Root tips

- White, healthy and growing
- Darkened or discoloured
- Rotting or dead
- Potbound, needing potting-up
- Roots dry, needing water
- Roots too wet
- Roots very hot
- Roots eaten, chewed or damaged by insects or other animals
- Roots or soil contains pests (give description)
- Roots or soil contains fungal or some other growth (give description)

Foliage (generally)

Growing tips

- Lush rapid growth

- Healthy but not lush
- Discoloured
- Looks sick

Older leaves
- Lush, very healthy
- Damaged
- Discoloured
- Has dead spots
- Some dropping

General foliage
- Thick
- Sparse
- Hardened
- Soft/tender
- Balanced shape
- Poor shape

Specific problems detected

List the names of any insects, diseases or other specific problems detected

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Recommended treatments (if any)

Plant variety concerned	Procedure	Urgent/non-urgent
	Stake	
	Prune	
	Relabel	
	Feed	
	Move to greenhouse	
	Move to shadehouse	
	Water	
	Move to …	

Holding stock

Sometimes plants are ready for sale before the market is ready to buy them. In these instances, the nursery manager faces the problem of keeping the plants alive and in peak condition without them growing any larger or becoming unmanageable.

There is a variety of options, including:

- slowing the growth rate by reducing fertiliser and water applications;
- storing in a dormant state;
- potting-up and selling as a larger plant;
- pruning back and allowing regrowth to occur;
- dividing suckering or creeping plants;
- developing the plant into a different product, such as a bonsai, topiary, basket or tub specimen.

Holding dormant plants

Some plants, particularly bulbs, deciduous plants and many herbaceous perennials, go through a period of dormancy (usually over winter), when growth slows considerably, or stops. During this time, the plants are easy to move, and for that reason are often sold as balled or bare-rooted plants (without any soil).

Bare-rooted plants and bulbs are much easier and cheaper to transport and store in a dormant state, hence the costs involved in marketing are reduced. However, it is essential to understand the requirements of dormant or semi-dormant plants. When plant growth slows, the plant's ability to resist pest and disease problems is reduced. The plants will remain dormant only as long as environmental conditions are appropriate, and placing them in a warmer situation might stimulate growth and make the plants susceptible to damage through drying out, or to physical damage when moved. They must be sold, potted or planted out before dormancy breaks and growth begins.

Bare-rooted plants should be stored with their roots covered by a moist (but not waterlogged) organic material such as wood shavings or moss, or they can be heeled into a bed of soil (the roots are covered by soil). They can be bunched together and do not need to be stood up, but be careful that plants rubbing against each other do not cause too many wounds.

Some varieties of herbaceous perennials, bulbs, corms, rhizomes and tubers can be stored dry on shelves in a cool dark place over winter; others must be kept moist, perhaps in containers covered with moist moss or shavings. Nurseries that grow plants which go through a period of dormancy may need to build special storage facilities to hold plants for several months after digging as orders are received and processed.

Plant modification

Shape, height, flowering and other characteristics of a plant are affected by many different things, including the environment and the way in which the plant is treated in the nursery. It is always preferable to grow plants that are uniform in appearance. Plants of a particular variety generally look and sell better when they are all are the same height, width and colour. Producing uniform batches of plants is an increasingly important aspect of nursery management.

Plant modification techniques are being more widely used to give desired characteristics. Some of the techniques are outlined below.

Developing a thicker or sturdier stem or trunk

This is done for deciduous trees where a thick and sturdy stem is important; for bonsai; and in warm climates or greenhouses where plants grow too fast and the stem can become too weak to support the lush, heavy top-growth. Growing-on nurseries prefer to buy plants with a thicker and sturdier stem because this, more than height, will affect the performance when they are grown-on.

- Moisture – Trickle-irrigated trees develop a greater trunk diameter than non-irrigated trees. Lack of moisture slows growth and causes stems to become thicker and sturdier.
- Light – Adequate light is important to producing thicker and sturdier stems. Placing plants in full sun or under artificial lights will promote stem development.
- Spacing – If there is plenty of space between plants, they do not need to grow upwards to compete for light, hence stems become thicker.
- Fertilising – Reduce nitrogen to reduce lush vegetative growth.
- Pruning – Cutting a plant back makes the trunk thicken, but it can also extend the time taken to get a saleable plant.
- Wind – Wind makes photosynthesates move towards the bottom of a plant rather than the top.

Making a plant taller

This is done for trees and rootstocks for standards.

- Light – In restricted light, plants grow taller to reach the light above, therefore shade can be used to promote taller growth.
- Moisture – Frequent watering promotes taller growth.
- Fertilising – Liquid nitrogenous fertilisers applied frequently usually promote taller growth than do slow-release fertilisers.
- Spacing – Plants spaced closely compete for the light and grow taller.
- Day length – In many plants, day length affects the formation of flower buds. By varying day length in some species (having a period when lights switch on at night, or using lights to extend the length of day), some plants can be kept in vegetative growth, in turn encouraging a bigger plant.
- Pruning – Remove side shoots to encourage terminal growth. Staking can also encourage more growth at the top of the plant.
- Chemicals – Gibberellic acid will encourage growth in some woody plants.

Developing a compact root system

This is done for trees and advanced plants grown in the open ground.

- Fertiliser – Applying fertiliser to soil at the base of the plant will encourage root growth to remain close to the base.

- Drip irrigation – This can keep the zone close to the base of the tree moist when the surrounding soil is dry, hence roots do not spread in search of water.
- Root pruning – Plants grown in the open ground can be pruned regularly with a U- or L-shaped tractor-mounted blade which cuts through the soil. Plants in containers (e.g. bonsai) are sometimes root-pruned to remove old or diseased roots and encourage healthier, more vigorous root growth.
- Cultivation – By rotary-hoeing between nursery rows, weeds can be controlled and roots cut, encouraging root growth to stay closer to the base of the plant.
- Copper screening – A copper screen is buried below the soil where root growth is to stop. Roots will not grow through the copper.
- Root-control bags – Made from a special fabric, these bags are buried below the ground with plants planted into them. Water flows through the fabric easily, so drainage is no problem, but roots will not grow through.
- Containers – Pots which absorb heat (e.g. metal and high-density plastics) discourage root growth close to the sides of the container. Pots which have better insulation properties (e.g. paper fibre or wood) encourage growth close to the sides of the container.

Developing compact, bushy growth

This is done to produce plants with greater stability and more attractive appearance, including indoor plants and potted colour.

- Pruning – Removing terminal growth forces more side shoots. Lack of staking encourages more lower growth.
- Environment – Exposing a plant to harsher or more exposed conditions, such as wind, generally encourages denser and lower growth.
- Chemicals – Some hormones, such as Bonzai, reduce the internodal space (gap between leaves on the stem).
- Light – Adequate light is essential for more compact growth. Avoid shading.
- Spacing – Allow more space between plants to reduce competition for light.
- Moisture – Less-generous watering can make some plants grow more compact.

Improving foliage colour and vigour

This applies to a wide range of plants including bedding plants, indoor plants, shade-loving plants and many general lines.

- Light – Different plants react differently to light. Many shade-loving plants will develop burnt or at least poorer-coloured foliage in full sun. Other plants (e.g. coleus, croton) can lose the brilliance of foliage colour in inadequate light.
- Moisture – Frequent watering and perfect drainage will promote better growing conditions and generally encourage more luxuriant growth. Poor drainage can reduce chlorophyll production and make leaves less green.
- Feeding – Different nutrients can affect the quantity and colour of foliage in different plants. Ample nitrogen usually promotes more leaf growth.

Encouraging flower development

Plants in flower normally sell better and are preferred by retailers.

- Plant maturity – Cutting-grown plants often flower earlier if cuttings were taken from more mature stock plants.
- Day length – Artificial lighting and shading can be used to stimulate (or stop) flowering, and control plant growth so that flowers are produced when the plant is to be marketed.
- Chemicals – Some chemical hormone sprays can encourage flowering, but many of these techniques are still largely experimental.
- Ringbarking – Partial or complete ringbarking of a stem (girdling) puts stress on a plant, which stimulates flowering in some species. However, it can kill some types of plants.
- Carbon–nitrogen ratio in propagation mix – Flowering is usually encouraged by a higher carbon–nitrogen ratio.
- Pruning – If done at the right time of year, root-pruning can stress some plants and stimulate flowering (e.g. wisteria). By understanding what type of wood flowers occur on, you can adapt pruning practices to retain or stimulate the appropriate type of growth for flowering.

What you do to a plant can have multiple effects. You might manipulate the watering or prune a plant to produce one effect, but you should always remember that your actions may have less desirable side effects.

Chemical growth modification

Various chemicals can have different types of effects on the growth habits of different plants. A few of the many chemical modifiers include:

- gibberellic acid – accelerates growth in some woody plants;
- succinic acid, maleic hydrazide, abscissic acid, ancymidol and other chemicals – inhibit growth in some plants;
- napthelene acetic acid (NAA) – can inhibit sprouting of buds after pruning on some plants.

Figure 5.5: Plants can be stimulated to produce flowers outside their growing season by altering light, temperature, humidity and other factors. This is usually carried out in a controlled environment such as a greenhouse.

Making flower out of season

Flowering occurs when there is a sudden change in the growing point from vegetative organs (leaves, stems and leaf buds) to floral organs. When this happens, the apical dominance usually weakens. The initial stimulus that causes this change in tissue type normally, but not always, originates in the leaves. As flowering tends to be related to the time of year, the initial stimulus is most obviously environmental.

Environmental factors

There are three possible types of environmental stimuli. The first is physical, for example changes in atmospheric pressure. The second is electrical, such as changes in pH. The third is chemical (changes in levels of certain chemicals). For example, more light increases photosynthesis, which increases levels of sugar. There are two types of chemicals involved in flowering: promoters and inhibitors. The promoters stimulate the process of flower induction. The inhibitors inhibit this process. The promoters and inhibitors do not work together in a balancing interaction. Rather, they affect each other through interference. For example, in Kalanchoe plants, short days produce promoter chemicals, but if more than one-third of the days are long, sufficient inhibitors are produced to stop the effect of the promoters.

Juvenility

A plant cannot respond to the effect of flowering promoters until tissue has gone through a phase change to reach maturity. It is possible for this phase change to be reversed and mature tissue become juvenile again.

Temperature

Temperature can affect time of flowering from sowing in three different ways:

- vernalisation, the process whereby cold temperature hastens flowering;
- rate of flowering process increases over a sequence of different temperatures. The final stage is an optimum temperature where flowering is most rapid;
- supra-optimal temperatures are stressful temperatures which delay flowering as temperatures become warmer.

Using light to modify plant growth

Greenhouse structures frequently use artificial lighting to assist growth. Plants respond differently to artificial lights, as all lamps radiate different qualities of the light spectrum. Consequently, the correct light depends upon the plant and the intended aim (whether to achieve a bushy plant or elongated plant). Each lamp therefore has advantages and disadvantages, depending on its purpose.

Table 5.2: Effects of artificial lights

Lamp	Stem elongation	Bushyness	Flowering	Other
Fluorescent	yes – slowly	yes	long period	horizontal leaf
Plant lamps (Gro-Lux)	yes – slowly	yes	late	deep green leaf
Wide spectrum	yes – quickly	no	quickens	light green leaf plants age fast
Vita-lite (Agro-lite)	yes – slowly	yes	long period	green leaf High intensity leaf expands
Deluxe mercury or metal halide	similar to fluoro			
High-pressure sodium	yes – slowly	yes	late	green leaf leaf expands extra-thick stems
Low-pressure sodium	yes – slowly	yes	yes	deep green leaf leaf expands very thick stems
Incandescent	yes – excessive becoming spindly	no	rapidly	pale thin leaf elongated leaf plants age fast

Examples of flowering control

Narcissus

Flower formation begins in the bulb during late spring and is completed by late summer or early autumn. The stage of flower development is important, as the bulbs give their best response to cool treatments once the trumpet has formed.

Natural cycle

In their natural habitat, southern Europe and the Mediterranean, the growth cycle of narcissus is as follows.

1. Hot dry summer – in early summer old leaves and flowers die, new leaves and flowers are initiated; in mid to late summer, leaf and flower formation are completed.
2. Warm autumn – new root growth begins, and shoot starts but does not emerge.
3. Cool wet winter – leaves emerge through soil, flower elongates within leaves.
4. Warm spring – rapid growth of leaves and flowering.

Forcing schedule

1. Harvest bulbs in summer.
2. Store at 17°C (63°F) until flower bud development is complete. This normally takes 2–4 weeks. Temperatures should not go above 20°C (68°F), otherwise flowering is delayed.

3 Cooling treatment before and after boxing: hold the bulbs at 9°C (48°F) for 6 weeks to promote early flowering. If you want late flowering, hold the bulbs at 17°C (63°F).
4 Plant bulbs in boxes of peat or straw. The earlier the plants are boxed the earlier they flower.
5 Place boxes in a forcing-house. This is done when the flower bud is at the neck of the bulb (later for later flowering, earlier for earlier flowering).
6 Grow-on in house, until flowering. A temperature of 15°C (59°F) is used when forcing.

Forcing with lights
Place boxes under clear or pearl tungsten lights (60 or 100W) 1–1.5 m (3–5') above the crop on a 1.1 m (3.5') grid spacing. Give 7 hours' lighting every 24 hours.

High temperature
For early-flowering bulbs, hold the bulbs at 35°C (95°F) for 5 days immediately after lifting in late spring. This treatment will not work once the warm summer weather commences.

Azaleas

Cool temperatures provide some vernalisation, so plants force flower buds more rapidly and evenly. Plants with well-developed flower buds (in the US) are stored at 10°C (50°F) or less. Keep at 2°C (35°F) (no lower) for extended storage, or 9–10°C (48–50°F) for short storage.

Growing plants are pinched to promote bushyness. After pinching, the plants are kept at 18°C (64°F) for 6 weeks on long photoperiods, followed by 18°C (64°F) with short photoperiods. The plants are then placed in cold storage, at 7°C (45°F) for 6 weeks, followed by a further 3–6 weeks' growth at 16–18°C (60–64°F).

There is some evidence that short photoperiods promote flowering; however, the photoperiod aspect is controversial. Low temperatures are known to be critical.

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6

Plant breeding and ownership

It takes many years to develop a new, desirable and commercially viable plant variety. Almost all the new varieties sold today are the result of breeding programs systematically designed to develop improved varieties. Every newly bred variety is rigorously tested for a range of characteristics. For every new plant variety released onto the market, there are hundreds of trialled and discarded varieties.

Figure 6.1: Selecting plants with desirable characteristics has been practised since the beginning of agriculture. Plant breeding now utilises more sophisticated techniques to cater to consumers' demands.

In the past any person could profit from the work of plant breeders; it was simply a matter of obtaining the propagating material then growing-on and selling the plants. This is no longer the case – legislation now recognises the rights of plant breeders, giving them ownership of the new varieties they develop. The introduction of Plant Breeders' Rights (PBR) has important legal and financial implications for the wholesale and retail nursery industry.

Genetic improvement of plants

The basis of modern plant breeding is genetics – the inheritance of characteristics from one generation to the next. Anyone wishing to breed plants must understand the fundamental principles of plant reproduction and genetic inheritance.

The genetic improvement of plants has been practised since the beginning of agriculture. Early farmers and gardeners selected plants with desirable characteristics such as faster growth, larger fruit, increased yields and resistance to diseases and pests. Unknowingly, those early farmers were creating strains of genetically improved plants, but without any knowledge of genetics or the mechanics of plant breeding it was impossible for them to deliberately transfer desirable characteristics from one line to another.

The greatest impact of plant breeding has been on agronomic crops, such as wheat, corn, barley and rice. Since the mid twentieth century, crop yields have increased by up to 300%, mostly as a result of selective breeding programs but also due to chemical fertilisers and other modern farming practices. In recent years, plant breeders have also targeted ornamental plants, selecting and breeding for improved flowers, pest and disease resistance, improved environmental tolerance and a range of desirable growth forms. Today the introduction and marketing of new and different ornamental cultivars is a very important aspect of the nursery industry.

The conventional method of plant breeding involves selecting traits by artificially transferring pollen from one plant to another, usually of the same species. The resulting progeny are grown under test conditions to identify their characteristics. In most cases, many generations of breeding, including crosses and backcrosses, are required before desirable varieties can be selected, tested and released for commercial use.

New technologies such as micropropagation and genetic engineering have revolutionised the techniques of plant breeding. While conventional plant breeding techniques still dominate in the creation of new plant varieties, plant biotechnology is playing an increasingly important role in breeding programs.

Mendelian inheritance: how plants inherit the characteristics of their parents

The first studies in genetics were carried out by Gregor Mendel in the 1860s. Mendel experimented with garden peas, which are true-breeding (homozygous) and capable of self-fertilisation. He chose seven well-defined contrasting traits, including differences in flower colour and seed shape. By carrying out many experimental crosses, Mendel examined how the traits were passed on to subsequent generations.

Mendel observed the traits that appeared in the first generation (F1), and counted the number of plants with contrasting traits in the second (F2) and third (F3) generations. He found that while plants of the F1 generation had only one trait, both contrasting traits appeared in the F2 generation. He called the traits that appeared in the F1 generation 'dominant' traits, and the traits that appeared only in the second generation 'recessive' traits. This is known as the principle of dominance, where some traits can entirely mask the appearance of another trait.

Mendel found that when plants of the F1 generation were allowed to self-pollinate, the recessive trait appeared in the F2 generation in a mathematical ratio of 3 dominant to 1 recessive. For example, when Mendel crossed round peas (WW) with wrinkled (ww) peas, the progeny (the F1 generation) produced round peas (Ww).

	w	w
W	Ww	Ww
W	Ww	Ww

Figure 6.2: Punnet square describing heredity of round or wrinkled seeds – F1 generation.

Mendel then crossed one Ww with another Ww to obtain an F2 generation which produced three plants with round peas (WW, Ww, Ww) to every plant with wrinkled peas (ww). This indicated that dominant and recessive genes were active in this characteristic. Those with Ww displayed the dominant feature. Only those with both recessive genes (ww) showed as wrinkled.

	W	w
W	WW	Ww
w	Ww	ww

Figure 6.3: Punnet square describing heredity of round or wrinkled seeds – F2 generation.

Mendel was not aware of the mechanisms of heredity, but we now know that the process takes place at a cellular level in the plant tissues. The units of heredity are contained in genes in molecules of DNA, located on the chromosomes. Each gene, or several linked genes, is responsible for determining the development of a particular characteristic, such as flower colour or plant height. During fertilisation of the plant embryo, genetic material from the parent plants is exchanged: some characteristics are retained and others may be altered, resulting in new traits in the offspring.

Mendel's principles

Mendel's experiments established two principles.

1. The principle of segregation. Hereditary characteristics are determined by genes that appear in pairs, one element of each pair being inherited from each parent. During meiosis, the pairs of genes are separated, which means that each gamete (sex cell) produced by offspring contains only one member of the pair that the offspring possesses.

2 The principle of independent assortment. The inheritance of a pair of genes for one trait is independent of the simultaneous inheritance of genes for other traits.

Plant reproduction

Plants can be divided into two classes on the basis of their reproductive behaviour: sexual and asexual. Plants that reproduce sexually can be further divided into those that are predominantly self-pollinating (selfing) and those that are predominantly cross-pollinating (outcrossing).

Phases of plant reproduction

The phases of reproduction in flowering plants are described below.

1. Flower initiation and induction – most horticultural plants have self-induced flowering (they flower when they reach a certain morphological stage) but some plants require photoperiodism (changes in day length), vernalisation (low temperatures) or hormonal stimulus to initiate flowering.
2. Flower differentiation and development – influenced by photoperiod in some species, and temperature.
3. Pollination – the process of transferring pollen from the anther to the stigma, either on the same flower or different flowers on the same plant (self-pollination), or on different flowers on another plant (cross-pollination).
4. Fertilisation – the pollen grain germinates on the stigma. It produces a slender tube (the pollen tube) that grows down the style into the embryo sac where it discharges sperm which unite with the egg to form the embryo (the new plant).
5. Fruit set and seed formation – as the embryo grows and develops within the ovary, the ovary enlarges and becomes a fruit; the embryo is surrounded by nourishing and protecting tissue (the seed).
6. Fruit and seed growth and maturation – the fruit reaches its maximum size and the seeds develop and mature.
7. Fruit senescence – the mature fruit stops growing and is replaced by ageing processes; the mature seed is shed.

Gamete (sex cell) production

Plant reproduction involves the process of meiosis – the division of cells so that the chromosome numbers are reduced from the diploid (2n) to the haploid (1n) number. During meiosis the nucleus of the diploid cell undergoes two divisions, resulting in the production of four haploid cells, each containing half the number of chromosomes of the original nucleus.

In flowering plants, meiosis occurs in the (male) anther and the (female) pistil usually during the bud stage.

The original chromosome number is restored during fertilisation, where one male gamete (1n) from the pollen unites with a female gamete (the egg, also 1n) to produce a diploid zygote or fertilised egg (2n). In this way, the offspring obtains chromosomes from both parents, resulting in genetic variation and plants inheriting characteristics from both parents. Zygotes develop as the embryo germinates in the seed, which gives rise to a new plant.

During fertilisation in flowering plants, a second male gamete unites with the polar nuclei in the embryo sac to produce the endosperm, the nutritive tissue for the developing embryo.

Genetic variations

Gene mutations

A change in the genetic message of an organism is called a mutation. The changes may involve alterations in the coding sequence or changes in the way the message is organised. In effect, a new allele is produced. The altered gene occupies the same place on the chromosome as the old gene.

In the case of plant breeding, mutations allow for the selection of new and desirable traits. Chemicals (e.g. alkylating agents) and physical agents (e.g. high energy radiations) are used to induce mutations and increase genetic variation in targeted plants.

Most mutations are harmful, but the capacity of organisms to mutate is very important as it allows evolution. For example, it may allow a species to survive when it would have died without the variation. In this way, mutations play an important part whereby living things adapt themselves (over thousands of years) to survive in a different environment. It has been estimated that one gamete in every 20 000 carries a new mutation.

Hereditary modifications

Hereditary modifications can be caused by changes in the gene number or structure.

Polyploidy

Polyploidy occurs in individual plants with more than two sets of homologous chromosomes. Polyploid cells arise during mitosis when the chromosomes divide but the cell doesn't, so that the new individual has twice or more the number of cells of its parents. They have less variability and are more stable than diploid plants because each gene is present twice as often; for example, a homozygous recessive gene only occurs in 1/16 of individuals compared to 1/4 of diploid plants. Is also means that many have relatively high fertility.

Polyploids occur at low frequencies in natural populations but their desirable characteristics have led to their deliberate selection and improvement. Many of our most important agricultural crops (wheat, cotton, sugarcane, bananas, tobacco, potatoes) and domestic garden flowers (pansies, chrysanthemums, daylilies) are polyploids.

Artificial polyploidy may also be induced by the alkaloid colchicine, which doubles the chromosome number.

Bud sports and chimeras

A bud sport is a mutation arising in a bud and producing a genetically different shoot. It occurs in asexually propagated plants and is characterised by the plant having the same genetic makeup in all its tissues. A chimera is also the result of a genetic mutation in an asexually propagated plant. A plant with a chimera differs from a bud sport in having two or more genetically different tissues, as a result of the mutation.

Most bud sports and chimeras are deleterious but there have been useful horticultural occurrences; for example, the Russet Burbank potato arose as a mutation of the Burbank potato and the Washington Navel probably arose as a bud mutation of a variety of Brazilian Orange. Variegated foliage is sometimes caused by chimeras.

Male sterility

Many crop plants have been found to contain genes for male sterility which inhibit pollen production. This has proved beneficial for plant breeders who select for parental male sterile plants in the mass production of F1 hybrids of crops such as corn and sunflowers.

Male sterility may be governed by a single gene which can be retained by crossing male-steriles (ss) with heterozygous fertile plants (Ss), giving half male-sterile and half fertile progeny. The male-sterile line is planted in alternate rows with the desired parent. The fertile plants in the male-sterile rows are rogued as soon as they are identified.

Male sterility can also be caused by cytoplasmic factors, which are inherited through the ovule of the female parent. This mechanism allows for reproduction of the female by fertilisation with fertile pollen.

Genetics vs environment

Two plants with the same genetic makeup will grow differently if they are reared in different environments. Although the genetic material may provide the messages and direction for good growth, the actual development of the plant will depend on environmental factors such as the availability of water, nutrients, temperature and length of daylight.

The genetic potential of a plant may be very good, but it will be fulfilled only if the plant is grown in good conditions. In any breeding program, the environment must be taken into account so that any genetic improvements can be identified separately from environmental effects.

Monohybrid and dihybrid crosses

Monohybrid crosses

The basis of plant breeding is crossing plants to produce variable offspring, from which new and desirable traits can be selected.

The simplest crosses are monohybrid crosses. A monohybrid is a plant that has resulted from the crossing of two parent plants, each from a pure (true-breeding) line (lineage). The parents differ from one another at one gene (locus) that influences a single character (trait) and are homozygous for different alleles of the gene.

The monohybrids (F1 generation) that result from crossing the pure-line parents are heterozygous at this locus (gene), inheriting a different allele from each parent. The monohybrids have identical genotypes and thus identical phenotypes. In the case of dominant and recessive alleles, the phenotype is the same as one of the parent lines (the homozygous dominant).

In a monohybrid cross, a monohybrid individual is either selfed (self-fertilised) or crossed with a similar monohybrid to produce progeny. The progeny (F2 generation) from this cross may display segregation for the trait which is influenced or controlled by the single gene.

Differences between F2 progeny for the trait are a result of segregation of alleles during meiosis to form the gametes, and subsequent fertilisation. These two processes enable alleles to combine (when the zygote forms), to give all three possible genotypes. In the case of dominant and recessive alleles, the two parental phenotypes reappear in the progeny of a monohybrid cross.

As described previously, Mendel reported the results of experiments from seven large monohybrid crosses in the garden pea. In one experiment Mendel crossed peas with purple flowers with peas with white flowers to produce monohybrid F1 progeny, which all had purple flowers (the dominant phenotype).

The shorthand used to describe the flower-colour genotypes in these crosses is as follows: purple-flowered parent (P1) line has genotype PP, the white-flowered parent (P2) line has genotype pp. (By convention, the dominant gene for a character is represented in upper-case letters, and the recessive gene is represented in lower-case.) The F1 monohybrid inherits a gene from each parent and therefore has the genotype for flower colour of Pp (and since the purple gene is dominant, these plants have purple flowers). The monohybrid cross resulted from self-fertilisation of these F1 plants is represented in the punnet square in Figure 6.5.

Mendel collected germinated seeds from the selfed F1 plants. There were 705 purple-flowered plants in the F2 generation, compared with 224 white-flowering plants. This was close to a 3:1 ratio, which he observed in all the monohybrid crosses he reported. The monohybrid cross Pp × Pp results in three possible genotypes, shown in Figure 6.4.

White-flowered parent

Purple-flowered parent	gametes produced	p only
	P only	Pp

Figure 6.4: Punnet square representing the cross to produce the F1 or monohybrid.

All progeny (F1 monohybrids) had the Pp genotype and had purple flowers.

Purple-flowered monohybrid

	gametes produced	P	p
Purple-flowered monohybrid	P	PP	Pp
	p	Pp	pp

Figure 6.5: Punnet square representing the monohybrid cross in which the F1 plants were self-fertilised.

Genotypes from the monohybrid cross above are expected to occur in the following ratios: 1PP (true-breeding purple-flowered):2 Pp (same as purple-flowered F1 parents):1 pp (true-breeding white-flowered).

The phenotypes are thus expected to segregate: 3 purple-flowered (PP and Pp genotypes):1 white-flowered (pp genotype).

Mendel's observed ratio of 705:224 (3.15:1) was extremely close to this expected ratio.

From these observations, Mendel inferred his first law: Two members of a gene pair (one from each parent) segregate from each other into the gametes, so that half of the gametes carry one member of the pair and the other half carry the other member of the pair.

Dihybrid crosses

In a dihybrid cross the two parental lines that have been crossed to produce the F1 differ by two characters, having different alleles at two loci (genes). The F1 plants are termed dihybrids.

An example of a dihybrid from Mendel's work with garden peas is the crossing of parent plants with round green seeds (RR yy) with parents with wrinkled yellow seeds (rr YY). The dihybrid progeny (F1) all had round yellow seeds (Rr Yy), with wrinkled seeds and green seeds being recessive conditions. After selfing these F1 (Rr Yy × Rr Yy), however, the (F2) progeny from the dihybrid cross gave 315 individuals with round yellow seeds, 108 with round green seeds, 101 with wrinkled yellow seeds and 32 with wrinkled green seeds – a 9:3:3:1 ratio of phenotypes. The genotypes generated as a result of this dihybrid cross is represented in Figure 6.6.

		Male parent			
	gametes	RY	Ry	ry	rY
	RY	RR YY	RR Yy	Rr Yy	Rr YY
Female parent	Ry	RR Yy	RR yy	Rr yy	Rr Yy
	ry	Rr Yy	Rr yy	rr yy	rr Yy
	rY	Rr YY	Rr Yy	rr Yy	rr YY

Figure 6.6: Genotypes from a dihybrid cross.

There are nine genotypes and four phenotypes created as a result of this cross. The expected frequency of progeny with round yellow seeds is given by adding the number of genotypes with a least one R and at least one Y allele in the table above. This occurs in nine squares. The expected frequency of progeny with wrinkled yellow seeds is all genotypes with two rr and at least one Y allele. This occurs in three squares. Progeny with round green seeds (R_ yy) also result from the genotypes in three squares. However, progeny with wrinkled green seeds (the double-recessive rr yy) occur in only one square. The expected phenotypic ratio is thus 9:3:3:1, which is close to Mendel's observed ratio of 315:108:101:32.

Observing these ratios in this cross and other dihybrid crosses led Mendel to formulate his second law: During gamete formation, the segregation of alleles of one gene is independent of the segregation of alleles of another gene.

It turns out that Mendel's second law is frequently violated when the different genes being studied occur on the same region of one chromosome. Where this occurs there can be strong distortion from the expected genotype ratios. The term 'linkage' or 'linked genes' refers to this phenomenon. It might be expected that if genes occur on the same chromosome, the expected phenotypes in the offspring resulting from a dihybrid (self-fertilised) cross would be of two kinds only. In the example above, if R and y (and, conversely, r and Y) were linked on the same chromosome, the dihybrid would produce only Ry or rY gametes and there would be only three genotypes (RR yy, Rr Yy and rrYY) and three phenotypes; 1 round green, 2 round yellow, 3 wrinkled yellow. However, due to the occurrence of crossing-over, the other phenotypes may result. The closer two genes are on the chromosome, the smaller the proportion of the other two phenotypes, known as recombinants. In the gametes that formed these recombinants, there has been crossing-over (recombination) during meiosis between the genes under study.

Quantitative traits

The inheritance of quantitative traits such as seed weight and growth does not usually follow a simple Mendelian inheritance pattern. There are thought to be two reasons for this: alleles at many gene loci influence each quantitative trait, and quantitative traits are generally strongly influenced by the environment.

F2 progeny from a cross of two pure lines generally results in individuals with a broad spectrum of values for the trait. They do not fall into the strict classes that are observed for the qualitative traits such as those studied by Mendel.

Quantitative traits have traditionally been studied using statistical analysis, particularly of heritability. The heritability of a trait indicates how much the average value of the trait can be altered by selection.

Plant breeding programs

Plant breeding has been defined as 'the art and science of improving the genetic pattern of plants in relation to their economic use'. It basically involves:

- creating variability, by breeding new plants from two different parents or by causing mutations to occur;
- selecting what you want from the variation that occurs in the new generation of plants.

In this way, plant breeders can create plants with desirable characteristics, ranging from improved flower colour, shape and size for the ornamental plant industry, to crops with superior yields and improved environmental tolerances.

There are a number of choices for plant breeders to make:

- parental plants;
- breeding methods;
- selection criteria;
- testing procedures;
- final choice of cultivars for commercial use.

The breeder can choose from a number of different methods of selection, and the one which is chosen will depend upon the objectives of the breeding program, the inheritance patterns of traits to be improved, and the parental population and its mode of reproduction.

Before starting a breeding program, it is essential to know whether the plant is self- or cross-pollinated and how it behaves when it is inbred or crossbred.

Breeding self-pollinated crops

The genetic effect of continued self-fertilisation in self-pollinated plants is to reveal the dominant and recessive genes. As Mendel's experiments showed, heterozygosity is reduced by half in each generation so that, after six or seven generations of selfing, a population will consist almost entirely of equal numbers of homozygotes. In this way, selection of characters by continued selfing results in pure lines – these plants are said to be 'pure-breeding' or breeding 'true-to-type'.

The following methods are used to breed self-pollinated crops.

Pure-line breeding

In pure-line breeding (also known as 'single plant selection'), the new variety is made of the progeny of a single pure line. It involves three steps:

1. selecting a large number of superior individuals from a genetically variable population;

2 raising the self-progeny of each over several years, preferably in different environments. Unsuitable lines are eliminated in each generation. When the breeder can no longer select superior lines by observation only, the third step is commenced;
3 replicating the trials to compare the remaining selections. This is done over several seasons (at least three years) to compare them with each other and with existing commercial varieties.

Mass selection

In mass selection, the progeny of many pure lines are used to form the new variety. Unlike pure-line breeding where the derived type consists of a single pure line, in mass selection the majority of selected lines are likely to be retained.

It is not as rigorous as pure-line breeding – obviously inferior plants are destroyed before flowering but overall many lines are kept and contribute to the genetic base. This gives the advantage of retaining the best features of an original variety and avoids the extensive testing required in step 3 of pure-line breeding.

Pedigree breeding

This is the most widely used method of breeding in self-pollinated plants. Superior types are selected in successive segregating generations (as in pure-line breeding) and a record is kept of all parent–progeny relationships. It starts with the crossing of two varieties which complement each other with respect to one or more desirable characters. In the F2 generation, a single plant selection is made of the individuals the breeder thinks will produce the best progeny. In the F3 and F4 generations, many loci become homozygous and family characteristics begin to appear. By the F5 and F6 generations, most families are homozygous at most loci; hence selection with families is no longer very effective. Only selection between them is possible.

Its main advantage is that the plant breeder can better exercise their skill in selecting plants than in other self-pollinating breeding methods. A disadvantage is the limitation on the amount of material one breeder can handle.

Bulk population breeding

In this method the F2 generation is planted out in large numbers (hundreds or thousands of plants), harvested in bulk and the seeds sown in similar numbers the following year. This process is repeated as many years as desired by the breeder. Natural selection reduces or eliminates those with poor survival value, while artificial selection is practised to rogue out obviously inferior types.

It is suitable only for the commercial breeding of small grains and bean crops. It has the advantage of avoiding the labour required in pure-line and pedigree breeding.

Backcross breeding

The purpose of backcross breeding is to improve a variety by transferring a desirable characteristic from another less-desirable variety. It involves making a series of backcrosses of the inferior (donor) variety to the superior one (recurrent parent), selecting for the desired characteristic at each generation.

At the end of backcrossing the gene or genes being transferred are heterozygous, but the other genes are homozygous. Selfing after the last backcross results in homozygosity for the gene pair, producing a plant that is identical to its recurrent parent except that it also has the characteristic of the donor variety.

A successful backcross program depends on the following:

- a satisfactory recurrent (superior) parent must exist;
- the desired trait must be able to maintain its intensity through several backcrosses;
- sufficient backcrosses must be carried out to ensure the genotype of the recurrent parent is recovered – a minimum of six backcrosses is used.

The method is popular because it gives the breeder a precise way of improving varieties that already excel in a number of characteristics.

Breeding cross-pollinated crops

Each cross-pollinated plant is heterozygous for many genes and continued inbreeding often results in loss of vigour and fertility, known as 'inbreeding depression'. It is therefore essential for a breeding program to maintain heterozygosity.

Single plant selection

Single plant selection (see 'Pure-line breeding' above) can only be practised in a modified form to avoid inbreeding depression. It may be possible to inbreed for a while, selecting the best phenotypes, but these must then be intercrossed to re-establish a degree of heterozygosity.

Mass selection

In mass selection, desirable individual plants are selected and the seed grown to produce the next generation, with the aim of increasing the proportion of superior genotypes in the population. It is a form of random mating with natural and artificial selection. It has proved effective in increasing gene frequencies for characters which are easily seen or measured, for example in developing corn varieties with improved protein content. It has not been effective in modifying characters, such as yield, which are governed by many genes and cannot be judged by the appearance of single plants.

Progeny selection, line breeding and recurrent selection have been developed to overcome such problems.

Progeny selection

Progeny testing allows the breeder to distinguish whether superiority among single plants is caused by genes or environment. It involves growing a small progeny (e.g. 10–50 plants) of each individual plant selected in the previous generation. Replicated trials repeated over several years and in different locations gives more accurate results.

Line breeding

This involves mass selection for several generations followed by saving seed from the most superior plants, then sowing this mixed seed in an isolated plot where the plants mate at random. The harvest from the plot then becomes the foundation seed of a new variety.

This technique is used to maintain pathogen resistance in a number of crops and, provided that an adequate number of not too closely related lines are included in the mixed seed grown in the plot, it avoids the problem of excessive inbreeding.

Recurrent selection

This involves selecting superior plants from a heterozygous population and propagating them by selfing. The selfed progeny are then intercrossed in all combinations to give material for more cycles of selection and intercrossing.

Backcross breeding

Backcross breeding in cross-pollinated crops has been used to transfer gene resistance into established, susceptible varieties.

The method for cross-pollinated crops uses a number of plants as recurrent parents, instead of one plant used in self-pollinating plants. This ensures the sample of gametes carried by one of the recurrent parents represents the gene frequency of that variety.

Hybrid seed production: an outline

When new seed-grown cultivars are to be bred and released for commercial use, the following process is used.

1 The breeders collect plant material to work with, including existing varieties and botanical species. They thoroughly research the species, finding out the plants' flowering behaviour, pollination and fertilisation, and method of cultivation, using books, the internet, scientific papers and information from botanists, specialist growers and gardening clubs.
2 Trial tests are conducted to see how the species behaves. Unsuitable species, which are too difficult to work with, are discarded.
3 The breeding program is commenced, crossing plants and inbreeding plants with desired characteristics until the offspring are sufficiently homogenous to be classed as pure lines.
4 The pure lines are crossed to produce new F1 hybrids. The seed of the crossings are sown and the plants assessed. Desirable plants are selected as test varieties.
5 The test varieties are trialled in the field or greenhouse. Trials may include testing seed quality, plant hardiness, pest and disease resistance, flowering quality – in short, testing the variety's overall performance.
6 Commercial seed production is then commenced by growing and crossing the parents of satisfactory test varieties. The hybrid seed is made by manual pollination. After the seed ripens, it is cleaned by hand or machine, ready for packaging and distribution.

Hybridising techniques

A step-by-step program

1 Select the parents. Selection is based on the desirable traits in the individual parents.

2 Synchronise flowering in the parent plants, if necessary. Plants in protected environments such as greenhouses can be subjected to short/long-day or manipulated temperature treatments to encourage flowering.

3 Collect and store the pollen. If synchronised flowering is not possible, pollen can be collected from flower buds 1–2 days before flower anthesis. On spring-flowering woody shrubs grown outdoors, shoots can be collected up to 2 weeks before the anticipated time of flowering; the shoots are forced indoors in a florist's preservative solution until the flower buds reach the appropriate stage of development.

   The anthers are removed from the flower buds by hand, using scissors or a sharp blade, or by gently rubbing the tip of the flower buds over a wire-mesh screen. The anthers are placed on absorbent paper and dried at room temperature for 24–36 hours, preferably at low humidity. The dried anthers and pollen can then be stored in a sealed container and placed in a freezer until needed.

   Pollen viability in storage depends on the species and the storage conditions – up to 2 years in *Prunus* species and as little as a few days for some grasses.

4 Emasculate the flower in self-pollinating species. In these species it is important to remove the anthers on the female parent before flowering, to prevent self-pollination (which would contaminate the hybridisation program). Anthers are carefully removed using fine forceps 1–2 days before anticipated flowering.

   Emasculation is often not necessary in cross-pollinating species. Many cross-pollinated plants are self-incompatible, meaning they cannot set seed from self-pollination or from pollen transfer between different plants of the same cultivar.

5 Pollinate the female parent. Pollen is transferred from the male parent plant or from previously collected and stored pollen to a flower on the female parent using a camelhair brush. The brush should be dipped in a solution of 70% ethyl or isopropyl between different hybridisations to kill the pollen and prevent it contaminating other crosses.

   Each flower should be tagged and labelled with the specific cross and the date of hybridisation.

   The plant may be covered with cheesecloth or pantyhose to prevent pollinating insects visiting the flowers.

   Mass pollination of a group of plants can be achieved by isolating the plants from others of the same species and allowing natural pollination by bees or other insects.

6 Observe fruit set and development. The fruit will swell, indicating fertilisation has taken place. Fruit should be allowed to dry on the mother plant but must be checked regularly to ensure the seeds are not expelled.

7 Collect the fruit and extract the seeds. The fruit is collected from the female parent at maturity and the seeds are extracted, dried and stored (if appropriate) according to the conditions appropriate for that species.

8 Germinate the seeds. Seeds are sown and germinated using the standard procedures for that species.

9 Transplant the seedlings. The hybrid progeny are transplanted to a greenhouse or field and grown-on according to standard procedures.

10 Select and grow-on the desirable hybrids. F1 progeny with interesting traits are flagged or staked; the remainder are discarded. The selected plants should be isolated from foreign pollen of compatible plants, and allowed to develop seed (the F2 generation).

Once the test varieties have been trialled, breeders increase seed production, either for the purpose of further testing or for commercial release.

Micropropagation

The development of micropropagation, or tissue culture, in the 1970s and 1980s was a major advance, allowing plant propagators to generate large numbers of clones (genetically identical individuals) in a short time. Tissue culture is now a standard procedure for propagating a wide range of plants in nurseries.

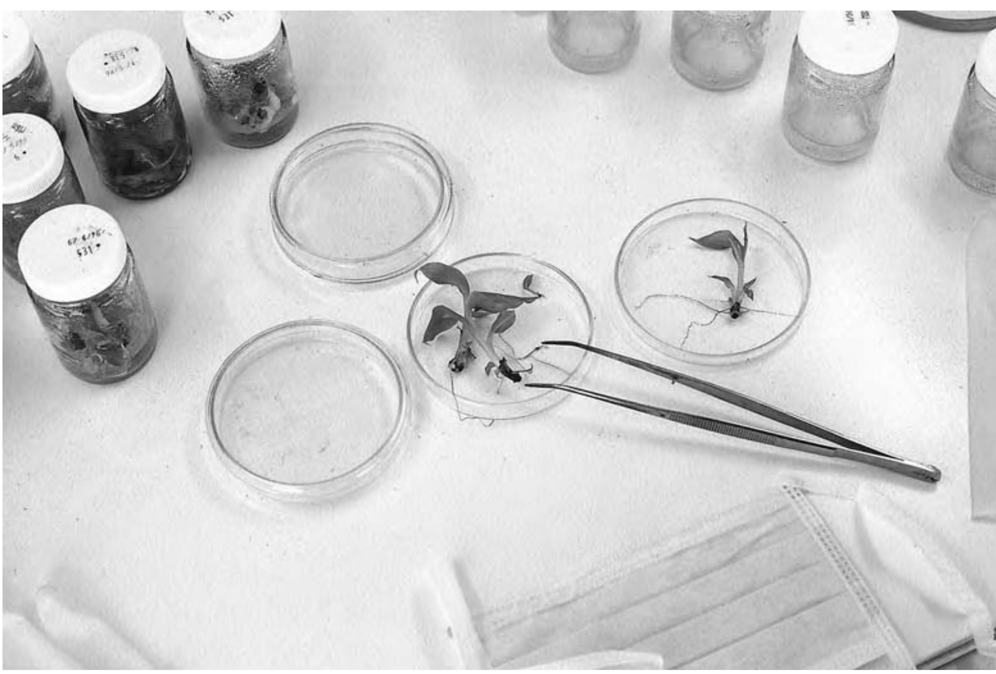

Figure 6.7: Banana plants being propagated by tissue culture. This method of propagation is asexual, ensuring that any desirable characteristics in parent plants are exhibited in the next generation.

Tissue culture has important ramifications for plant breeders, providing a means of rapid regeneration of clones and of producing genetically modified plants. It allows for procedures that would not be possible using conventional methods, including the following:

- 'embryo rescue', which enables breeders to perform crosses between distantly related plants. This involves culturing embryos in tissue culture and regenerating whole plants;

- recovery of hybrids and plants resulting from protoplast fusion depends on regeneration in tissue culture;
- most methods of plant transformation rely on regeneration from plant cells grown in tissue culture.

Plant breeders' rights and trademarks

It is important for people working in the nursery industry to understand the legal, financial and moral obligations associated with plant variety ownership. Most new plant varieties sold by nurseries are registered with the Plant Breeders' Rights (PBR) scheme. PBR gives legal rights to the original breeder, and there are significant financial penalties for any person or organisation that infringes those rights.

The PBR scheme was developed for two reasons: to provide legal protection to the original breeder of a variety, ensuring that other growers do not unfairly gain from the production or sale of the variety, and to encourage plant breeding and innovation through the grant of a limited commercial monopoly. It gives exclusive commercial rights to a registered variety, including the rights:

- to produce or reproduce the material;
- to condition the material for the purpose of propagation;
- to offer the material for sale;
- to sell the material;
- to import and export the material.

Anyone wishing to propagate, purchase or sell a registered variety must obtain consent from its owner. The owner may be the original breeder or a licence-holder to whom the breeder has sold the rights to grow and sell the plant. The owner claims royalties from propagators, growers and dealers, as recompense for their work and the costs involved in breeding and developing the variety.

PBR protection is available in most of the major countries involved in horticultural and agricultural production. The criteria for registering a new variety vary, but the essential principles are similar and conform to the 1991 International Union for the Protection of New Varieties of Plants (the UPOV Convention). More than fifty countries have adopted the UPOV Convention.

The variety has to meet strict criteria of distinctiveness, uniformity and stability (DUS); it must be new and it must have a recognised breeder (discoverer). To meet the criteria of newness, the variety must not have been sold to others within the country more than twelve months before lodgment of the application, or more than four years for overseas sales (six years for trees and vines).

There are exceptions to the exclusive use of registered varieties. In keeping with the PBR scheme's aim of encouraging plant innovation, other breeders may use registered varieties in their breeding programs and researchers may use registered varieties for non-commercial experimental purposes. Farmers are permitted to save seed from registered varieties for the purpose of replanting on their own land.

Once granted, PBR is normally valid for 25 years for trees and vines and 20 years for all other plants. When it expires, the variety is in the public domain and available to all.

National and international PBR registration

The registration process takes at least two years for most varieties and involves the breeder carrying out comparative field trials, following UPOV guidelines, to demonstrate distinctiveness, uniformity and stability. The PBR office may also conduct field trials.

Breeders normally register a new variety in their own country. Members of the UPOV Convention have the opportunity for equivalent rights to be filed in foreign countries.

Marketing PBR plants

Breeders may choose to propagate and market a PBR-registered plant themselves or may license the variety to growers on the condition they pay a royalty on sales.

Plant breeding and marketing is taking place on an increasingly international scale, with the rights to a variety owned by a plant breeder in one country, who licenses the plant to overseas growers. In these cases, the breeder appoints an agent to represent their interests both nationally and overseas. The agent might deal with such things as administering licences, distributing material, monitoring sales and collecting royalties.

Trademarks

Before the introduction of PBR and PVR (Plant Variety Rights, the forerunner of PBR), breeders used trademarks to obtain legal protection. The trademark may be used as a promotional name but it cannot be used as a registered variety name.

Patents

Patents differ from PBR in that they are used to protect a process or the components of a variety, for example a technique of gene sequencing. PBR protects the end product, the plant variety, as a whole.

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7

Pest and disease management

Pest and disease problems can decimate nursery stock, causing direct and indirect damage that may leave stock unsuitable for sale. Nursery managers must have plans to control unwanted organisms wherever they interfere with the operation of the nursery.

Chemicals kill pests and diseases effectively, but there can be problems if you don't use the right chemical or the right method. There are other ways to control pests and diseases, but other methods rarely give the complete control that chemicals do.

Integrated pest management

The preferred option for pest management these days is a combination of control techniques. The concept is that:

- nothing is overused to the detriment of the environment, or to the extent that pests build resistance to the control technique;
- each technique weakens the pest or disease a little bit more. The overall effect is a better control;
- expensive controls such as chemicals are used in limited quantities, keeping costs lower.

This idea of using a combination of different control techniques which each contribute to the overall control is sometimes called 'integrated pest management' (IPM). IPM relies upon creating, as far as possible, a growing environment with a balance between sustainable environmental practices and profitable nursery management.

The main ways of controlling pests and diseases are resistant plants, hygiene, cultural controls, physical controls, biological controls, chemical controls and weed controls.

Identifying the problem

If a plant is not healthy, it is probably due to one of the following:

- an animal pest, such as insects, arachnids, birds, mammals and other animals;
- a disease, such as fungi, bacteria and viruses;
- an environmental problem, such as too much or too little light, temperature, humidity etc.;
- a nutritional problem, where a plant is not getting the right nutrients in an appropriate combination or quantity.

Identifying pests

If you think or know a problem is caused by an insect but aren't sure what insect it is, try to see how it feeds. The following list may help you quickly identify insects doing damage to a plant. They are grouped according to the type of plant damage they cause. The list is not exhaustive, but it should cover most common types you will encounter:

- insects (and other pests) which chew above ground – ants, armyworm, bugs, beetles, caterpillars, crickets, cutworm, earwig, flea beetle, grasshopper, leafminer, leafroller, leaf skeletoniser, mice, possums, rats, sawfly, slug, snail, springtail, weevils;
- insects (and other pests) which suck plant parts above ground – aphids, harlequin bug, lacebug, leafhopper, mealybug, mite, psyllid, scale, squash bug, thrip, treehopper, whitefly;
- insects (and other pests) which feed below ground – root aphis, root nematodes, root borer, rootworm, root weevil, woolly aphids, wireworm, beetle larvae;
- borers (including fruit borers) – codling moth, bark beetle, corn earworm, white pine weevil, melon worm, longicorn beetle, european apple sawfly.

Identifying diseases

Diseases of plants include fungi, bacteria and viruses. The symptoms of diseases are various, and can seem similar to and occur in conjunction with insect pests. The most commn diseases are listed below:

- anthracnose – dead spots, usually sunken;
- blight – quick death of plant parts;
- canker – dead tissue in one place only;
- damping off – rotting of young plants at soil level;
- galls – abnormal swellings;
- leaf spot – dead or off-colour spots on leaves;
- mildew – young growth becomes distorted and grey/white/powdery;
- rots – decaying tissue;
- rust – brown/orange spots or stripes;
- smut – sooty/powdery covering;
- sooty mould – similar to smut (associated with insects);
- wilt – drooping foliage.

Figure 7.1: These brownish-orange spots on a peach tree are the fungal disease commonly known as rust.

Identifying viruses

Viruses are microscopic pathogens which live inside the bodies of other organisms. They can have a wide variety of effects on plants, one of the most common being a change of colour in leaves and/or flowers. Infected leaves often develop light green or yellow patches (a variegated effect) due to interruption of chlorophyll production, reducing photosynthesis.

Viruses can kill plants but more commonly make them sickly, less attractive for sale and slower-growing. In other cases, virus can cause distortion in the growth including twisting, blistering or other distorted formations in leaves, stems, roots or flowers. In extreme cases, leaves can be reduced to a central midrib with no leaf blade at all.

Plants which are very commonly affected by serious virus problems include gladioli, carnations, chrysanthemums, strawberry, passionfruit, daphne and tulip. There are others, but you should watch these in particular.

Viruses are not as easy to control as most other plant problems. Once a plant cell is infected with a virus, the only way to eradicate the virus is by killing that plant cell. Generally, prevention is the only cure.

- If a plant is infected with a virus, remove and burn the plant.
- When dealing with plants which are very susceptible to viruses, make sure that you always start out with clean stock.
- Control insects. Viruses are carried from one plant to another by sap-sucking insects. Fungi and nematodes have also been known to spread viruses.
- If possible, use plant varieties which are more tolerant to viruses.

Resistant plants

Healthy plants

As a general rule, healthy plants will show greater resistance to pest and disease attack, and will be more likely to recover if they are attacked. When propagating your own plants make sure you only use propagating material from healthy and vigorous parent plants. When buying plants make sure you choose healthy-looking ones. Carefully inspect the plant, the surface of the potting mix, the plant container and so on for signs of pest and disease infestation or other problems. When selecting bare-rooted plants, such as fruit trees, carefully check the roots for signs of damage, abnormal swellings or growths. A little time and care when selecting your plants will usually mean a big reduction in pest and disease problems later.

Resistant varieties

Some plants seem to have few pest and disease problems. These plants are said to be resistant or tolerant. In some cases this is because pests and diseases are simply not attracted to that type of plant; in other cases the plant directly affects any insects or pests attempting to live on it, for example by exuding chemicals that repel the pest. Some plants also have a greater ability to withstand insect or disease damage. In some cases, the regular pruning of foliage by insects can help to keep plants vigorous. By choosing resistant or tolerant plants you will reduce the likelihood of problems.

Figure 7.2: *Anigozanthus* spp. are renowned for their vulnerability to inkspot fungus. However, there are many new hybrids that are resistant to the fungus.

Hygiene

The easiest way to control pests and disease is to avoid getting the problems in the first place. There are two main ways of doing this. One is to practise good hygiene, which every nursery can and should do. The other is to avoid growing plants which have pest or disease problems. This is not always easy, as many popular plants are prone to pest and disease attack. It is also important to have proper quarantine practices prior to allowing stock to enter the nursery system.

Figure 7.3: Hygiene is a key factor in preventing disease outbreaks. Potting benches such as these should be disinfected regularly.

Pest and disease transmission

Pests and diseases can spread in many different ways, including:

- dipping healthy cuttings in hormones or water into which diseased material has been dipped;
- through irrigation (e.g. from contaminated water sources), rainwater (dripping off structures or diseased plants or splashing up from soil) or surface runoff;
- soil-borne diseases on the hose if it's dropped on the ground;
- soil on the bottom of pots and trays;
- on tools, clothes, shoes and workers' hands;
- contaminated soil mixes or pots;
- on vehicles or people visiting the site;
- infected plant material;
- animals.

Maintenance of sanitation

- Treat all soil with steam or chemical fumigation.
- Segregate clean and treated pots. Never store clean pots on the ground. Clean all containers before use.
- Don't use or transplant diseased seedlings or cuttings (destroy by burning).
- Use clean plant material from a specialist propagator (e.g. if buying tubestock to grow-on, check it comes from a reputable supplier).
- Dipping cuttings in sodium hypochlorite (bleach) will kill most pests and diseases. Sodium hypochlorite can bleach clothing and burn cuttings if too strong, so dilute to use.
- Take cuttings from the top of plants. This is the cleanest part.
- Use sterile tools. Wash with Dettol, Biogram or another horticultural sterilising agent.
- Keep cutting tools sharp to prevent tearing or ripping plant material, which may make the plant more susceptible to attack.
- Wash tools before using on a different plant.
- Place clean plant material on cleaned and sterilised benches.
- Segregate propagation activities from sales and growing-on areas.
- Avoid handling treated soil unnecessarily.
- Wash hands with hot water and soap before handling plants.
- Avoid splashing water near sterilised soil, pots and benches.
- Place pots on well-drained surfaces such as concrete or asphalt, or non-corrosive metal for benches. Blue metal and some other types of crushed rock are acceptable. Trays should be set above the ground.
- Hang hoses on a hook. Don't leave them on the ground.
- Ensure that any machinery used where pests, diseases or weeds are a problem is thoroughly cleaned before being used elsewhere.
- Avoid having muddy areas. If possible, improve the drainage. Have drains take excess water away rather than redistribute it, and any diseases which might be in it, elsewhere onsite.
- Clear away any weeds near your nursery. Many weeds act as hosts to diseases and pests which affect your crops.
- Place any possibly diseased plants in an isolated or quarantine area.
- Keep a close eye on plants and apply control methods to pests and diseases as soon as they are detected, to prevent their spread.
- Maintain a regular pest and disease program.

Cultural controls

Correct positioning

Choose the right plant for the right position. Growing your plants in a position suited to them will reduce pest and disease problems. Plants which are grown in the wrong circumstances will be stressed and prone to pest and disease problems.

Timed planting

Growing crops early in their normal growing season before pests and diseases have a chance to build up can often help reduce pest and disease problems. For example, annual plants such as vegetables and flowers can be sown early, perhaps in a greenhouse or coldframe, so that they can be established outside as early as possible.

Increased plant diversity

A nursery which produces a greater variety of plants has less chance of suffering serious losses as a result of pest or disease infestation. This needs to be balanced against having the space, expertise and equipment required to produce the greater variety.

Crop rotation

Different crops will attract different pest and disease problems. Where possible, rotate crops so that the host plants are always different. For in-ground nursery production, crop rotation plays a particularly vital role in controlling root diseases. Crops also have different nutritional needs, so rotation also prevents exhaustion of specific crop nutrients in the soil.

Irrigation

In hot weather, too much water on the surface of the ground or leaves will encourage fungal diseases and some insects. Drip irrigation can decrease these problems. Flood-irrigating an area occasionally can drown some soil pests.

Climate modification

Controlled growing conditions can reduce pest or disease populations by creating environments they don't like. For example:

- improving ventilation will often help control fungal problems;
- shady conditions may promote fungal and other diseases or weaken a plant, leaving it more susceptible to attack;
- creating drier or damper conditions will often deter different pests, for example some ants don't like very moist soil;
- mist and overhead spray irrigation fosters disease more than flood or trickle irrigation does.

Quarantine

When importing material into a nursery system, it may be wise to isolate the material in a special quarantine area prior to introducing it into the main nursery area. This allows time for any previously undetected pests or diseases to emerge and be dealt with in the appropriate manner. Procedures such as this can prevent a pest or disease outbreak in the main area of the nursery. In some instances, there are strict government regulations on quarantine issues, so nursery managers need to keep abreast of any legislative changes in their area.

Physical controls

Hand removal

Many pests can be simply removed by hand, especially if you catch the problem early, before it spreads too far. Snails and slugs can be squashed or otherwise killed. Small infestations of caterpillars can be squashed between your fingers (preferably while wearing gloves) or knocked to the ground and squashed with your feet. Leaves with fungal problems or insect problems such as scale can be picked off and burnt.

Pruning

Pruning can be used in two ways to control pests and diseases. The first is by modifying the shape of the plant to make it less likely to attack, for example by removing damaged or rubbing branches. It could also be opened up by removing growth to improve air circulation, or removing areas that could provide shelter for pests. The second way is by directly pruning away plant material already affected by pests and diseases to prevent the spread of such problems. The pruned material should be burnt.

Hosing

Some pests can be readily knocked off plants by hosing them with a strong spray of water from a hose. This is particularly useful for non-flying pests.

Traps

Traps work by catching pests, either attracting them into a trap some distance from the crop, or placing a trap somewhere where the pest normally occurs. Traps may be a sticky substance placed in the path of a pest so that the pest becomes stuck, or a container with a lure to attract the pest inside where it can be collected later.

Typical traps include:

- yellow attracts many insects, such as aphids. Yellow cards covered with something sticky, such as honey, will attract insects which then stick to the card surface. The cards are periodically collected, burnt and replaced with new ones. Other colours will attract different pests, for example white will attract thrips;
- several layers of corrugated cardboard around a tree trunk in early spring will attract codling moth. Remove in summer with the larvae attached and burn;
- tinfoil hung near plants will reflect light. This can confuse aphids and reduce attack. Foil can also provide extra light and warmth early in the season;
- light traps attract moths and butterflies, thus reducing caterpillar populations. Red, yellow or orange lights are generally avoided by most insects; white, green or pink fluorescent lights can also be effective. Some commercial light traps incorporate an electric grid which kills insects attracted to the light. These traps need regular cleaning to work well.

Physical barriers

Physical barriers can often be a very effective means of preventing pests and diseases from reaching plants. Examples of physical barriers are:

- fences or tree-guards to prevent rabbits, dogs, grazing animals and children from coming in contact with plants;
- netting to keep out birds and fruit bats;
- greenhouses to isolate plants from insects, fungal spores etc.;
- metal collars on trees to stop possums or crawling insects climbing up;
- insect screens on small cages over young plants or to cover a ventilation opening on a greenhouse;
- wood shavings or diatomaceous earth used as a barrier against snails and slugs, which are deterred from crawling over surfaces which feel too rough;
- sticky substances such as bituminous paint on the base of a tree trunk to stop ants crawling up into branches.

Repellent devices

There are various devices that can be used to repel pests, particularly birds. The devices usually need to be moved around and may work for only a short time, so use them only at the most critical times:

- scarecrows will deter birds and other animals. When a scarecrow first appears, birds and animals will sometimes avoid that area for a few days, even weeks, until they become used to it. To get the most out of a scarecrow, put it up just as your fruit or flowers are starting to mature, change its position and appearance every few days and keep parts of the clothing loose so they will blow in the wind and create movement;
- bird wires hum in the wind and can scare away birds;
- strong-smelling substances such as camphor, garlic and pepper can deter animals with a keen sense of smell, such as dogs, possums, mice and rats;
- scare-guns are commonly used to protect fruit and vegetable crops, but are only suitable for isolated nursery sites as the noise can be very annoying.

Sterilisation

One way to control soil-borne organisms and pathogens is fumigation. It is used for sterilising potting mixes, propagating mixes and soil areas to be planted up in greenhouses typical of the cut-flower industry.

Traditionally, fumigation involved applying a poisonous chemical – usually methyl bromide – to the soil, allowing it to penetrate the soil as a vapour and holding it in that condition for some time, usually with a sheet of plastic, to eradicate unwanted organisms. Although a very effective soil sterilising agent, methyl bromide is toxic to humans and its use has been banned in most countries. Some chemicals are still available for use as soil sterilising agents, but their use is under review in many jurisdictions.

In the future, the most common method for sterilising soil and growing media will be through non-chemical fumigation using steam or solarisation. Most organism die at high temperatures and these methods offer an effective and environmentally friendly method of controlling unwanted organisms.

Steam

Steam sterilisation or pasteurisation of growing and propagation media will kill most pests and diseases, and most weed seeds. Now used widely for potting mixes and growing media, the temperature of the steam treatment can be controlled to target particular organisms. This results in fewer pest, disease and weed problems in growing areas or containers, making subsequent control programs much easier.

Solarisation

In this method, clear plastic is spread over the soil and the edges tucked into the soil or held down by heavy objects. High temperatures created beneath the plastic by sunlight will kill existing weeds and encourage the germination of weed seeds in the soil, then kill the new seedlings. This technique often kills other pest and disease organisms, but is suitable only for relatively small areas. The plastic can be removed (perhaps after a couple of weeks) and the area planted.

Biological controls

Biological control is the use of a biologically derived agent such as a bacteria, insect or animal to control pests, diseases and weeds. These living things act as predators or parasites that attack and harm the problem agent. In the nursery industry, the most widely used biological control methods are the release of predatory mites to control some pest mite species, particularly red spider mite, and the use of sprays containing *Bacillus thuringiensis* which specifically attacks caterpillars.

A balance usually develops in nature among organisms, both plant and animal. Certain organisms are antagonistic to others and retard their growth. Environmental or human-induced changes that upset this balance by eliminating one of the organisms can lead to explosive proliferation of the others, and to subsequent attacks on vulnerable crop plants. Biological control in such a situation would consist of introducing an organism antagonistic to the pest, thus bringing the pest under control.

Olive parlatoria scale threatened the existence of the California olive industry, but two parasitic wasps introduced from Asia became well-established and practically eliminated the scale. Similarly, cottony cushion scale was introduced to California from overseas, without its natural predators. The importation of vedalia beetles from Australia virtually eradicated the pest very quickly, and the beetles still keep it in check.

Advantages of biological control methods

- Antagonistic organisms don't damage plants, in contrast to many chemicals.
- No residues are left, unlike the use of many chemicals.
- You don't have to wait before harvesting produce, as commonly occurs when using chemicals with a withholding period.
- It is less costly than using chemicals and, unlike chemicals where repeat applications are generally necessary, predators and parasites may offer continuous control as they continue to breed.

- The organisms can spread, often very rapidly, controlling pests and diseases over large areas.
- Pests and diseases are unlikely to build up resistance to the organisms, as often occurs when using chemicals.
- The organisms are generally predators or parasites of specific pests or diseases and will not affect other organisms.

Disadvantages of biological control methods

- Biological control programs often have to be large-scale to be cost-effective.
- They are often very slow-acting in comparison to chemicals.
- The degree of control can be less precise than with chemicals.
- It can be very hard to find predators or parasites of some pests, especially ones specific to that pest or disease rather than to a number of organisms.
- The mobility of antagonistic organisms can sometimes be a disadvantage. What may be a pest or disease in one area may not be one elsewhere; for example blackberries are a declared noxious weed in some areas of Australia, but are also grown commercially for their berries. The introduction in recent years of a blackberry rust to Australia as a means of blackberry control may affect crop varieties.

Insect predators

Many insects are good predators of pests:

- ladybird beetles and their larvae eat aphids;
- hoverflies eat aphids;
- lacewing will control mites, caterpillars, aphids, thrips, mealybugs and some scales;
- praying mantis eat most other insects, pests or not.

There are many other useful insect predators, and as long as there is a suitable environment and the use of chemical sprays is minimised, they can do much of the control work for you.

Predatory mites

These are a parasite of the two-spotted mite, a common pest throughout much of Australia and over a wide range of crops. When they are released, distribute them as evenly as possible and avoid watering for at least 24 hours. Limit the use of chemicals for at least a few weeks after releasing the parasitic mite.

Bacillus thuringiensis

Bacillus thuringlensis, sold as Dipel®, it is a naturally occurring bacteria supplied in a powder-like form. A selective control, it is used on a wide variety of caterpillars.

Pheromone traps

Female insects, such as fruit flies and codling moths, give off a scent (pheromone) which attracts males for reproduction. Traps using pheromones as an attractant have been devised. These traps are used by scientists to see how many insects are present in one area compared to another, and whether the numbers of insects are increasing. Pheromone traps are available commercially as a control method for specific pests such as fruit fly.

Maintaining predators and antagonistic organisms

Conservation of existing natural enemies requires changing to selective spraying programs. You must build up the natural enemies to a useful level by using selective chemicals, by changing when you spray – some insects are active at different times of the day – and by reducing the amounts of chemical used.

Future developments in biological controls

New natural enemies can be developed by scientists growing larger numbers of predators or parasites, or by adding additional numbers of natural enemies collected or purchased from elsewhere. Producing and marketing biological control agents has now become a major business in Europe and the US, with small-scale production also in Australia.

Other approaches to biological control under active research are the development of plants with increased resistance to pests and diseases; the use of natural chemicals such as hormones or sex scents to attract (to a trap or away from plants), repel or kill these types of problems; the use of sterile insects to upset reproductive cycles; and the use of plant derivatives, such as pyrethrum, as pesticides.

Chemical controls

Many nurseries use chemicals extensively to control pest and disease problems, either as part of a routine pest and disease control program or as a solution to detected problems. The following information is provided as a guide. Controls on the use of chemicals vary between different jurisdictions and are regularly revised. In some cases, chemicals are banned and/or can only be applied by licensed contractors. If in doubt, check with the regulatory authority in your state or territory before using chemicals.

Routine chemical programs can be a significant expense in a nursery, but they do increase the likelihood that stock will look good at all times and that production schedules are not interrupted by unexpected infestations of insects or diseases. However, regular use of chemicals also has disadvantages. These include potential pollution of your property and surrounding areas, possible development of pesticide-resistant strains of pests and diseases, and health risks to staff and customers from poor pesticide storage, handling and use.

These problems can be minimised by careful selection of chemicals used, how they are used and when they are used. Chemicals which persist in the environment for long periods such as years are best avoided. By using different chemicals to treat the one problem, issues such as the compounding effect of an individual chemical building up in the environment, or encouraging pest resistance to develop, are minimised. Safety precautions and recommended application rates given by pesticide manufacturers should always be thoroughly read and closely followed.

Advantages of chemical controls

They are reliable, involve low labour costs, cover broad areas and offer quick results.

Disadvantages of chemical controls

They may kill other organisms, including desirable species; sprayed areas are vulnerable to new pest infestations; you will not gain status as an organic producer; and they may leave poisonous residue in the soil.

Control program

Different approaches to chemical control may be required at different stages of plant production. There are basically five stages at which chemical pest and disease control should be implemented:

- establishment and maintenance of stock plants;
- collection of cuttings;
- cutting preparation facility;
- cutting preparation and striking techniques and methods;
- aftercare facility and care of cuttings.

Forms of chemical control

Chemicals can be applied as granules sprinkled at the base of the plant, dusts puffed or blown onto plants, or a liquid spray. Granules have the distinct advantage of being safer

Figure 7.4: Spraying to prevent and treat disease is important, but it is essential to follow the manufacturer's directions. This camellia has leaf damage caused by improper use of Benlate spray.

and less likely to be absorbed into the human body. They generally go only where they are put, but sprays and dusts may be spread by the wind or poor spraying technique to other areas, wasting the chemical and perhaps causing pollution or spray-damage to plants.

The action of sprays and dusts is variable. Systemic pesticides act by being absorbed by the plant, whereas contact pesticides work by direct contact with the problem. Selective pesticides kill only the target organism; non-selective pesticides may kill desirable organisms. Some pesticides are residual, remaining in the soil after use.

The type of sprays used and the frequency recommended will differ from nursery to nursery depending on local conditions such as weather patterns, the types of problems in the area and the types of plants grown in that nursery. For example, plants with hairy foliage such as *Tibouchina* sp. should not be sprayed, as this can increase disease in those plants.

Some nurseries use subcontractors to do spraying. This works well for a routine spray program if the contractor is competent and reliable, but it is not usually appropriate for nurseries that treat problems only as they arise. Problems must be treated as soon as they are detected, which means that the contractor must be available when the problem occurs. This can often be a problem, particularly if the contractor is in demand.

When using a new pesticide, one with which you are not familiar or in a new situation, it is worthwhile to do a trial application on a small section of the area. This allows you to gauge results before doing a full-scale application.

The following is a not an exhaustive list, but a guide to the most common chemicals used in nurseries. Many of the compounds are highly toxic and, if used incorrectly, can harm humans, livestock, soil and waterways. If you have any doubt about the use of these chemicals, consult your supplier or the regulatory authority in your state or territory. Always read the label before use.

Insecticides

Pyrethrum
This is a naturally occurring plant extract used widely in sprays and aerosols for the home. It has also been used successfully in broader-scale agricultural production. Synthetic pyrethroid-type sprays are now widely used in agricultural and horticultural production. To be effective, it must make contact with the insect pest. It is toxic to fish.

Sulfur
Toxic to mites and scale, it is more commonly used as a fungicide. Not suitable for use in hot weather.

Rotenone
Also known as Derris Dust, it is an extract from a plant root. It is non-selective and non-systemic and has a low level of persistence in the environment. It is often mixed with sulfur compounds. It is toxic to fish.

Hydrocarbon oils
These include white oil, made from paraffin, and winter oil, a petroleum-based product. They are used as contact pesticides for sap-sucking insects such as scale and mites, and can damage the foliage of some plants.

Nicotine
Extracted from the tobacco plant, it kills sap sucking insects. It is non-systemic and non-residual. Toxic to mammals if swallowed.

Neem
Neem is a plant extract that interferes with insects' hormone system, preventing reproduction. Not yet widely available, it offers great potential as a non-selective, non-residual insecticide.

Carbamates
Including one plant extract, these compounds act both systemically and on contact. Most are non-selective and work by interfering with the nervous system. They are less persistent in the environment than organophosphates and organochlorines.

- Carbaryl is a contact insecticide used for beetles, and moth and butterfly larvae. It is particularly effective against leaf-eating insects and is toxic to most insects, including bees.
- Methiocarb is a non-systemic chemical for poisoning invertebrate animals such as snails, slugs and slaters.

Organophosphates
A large group of pesticides with variable levels of toxicity, these work by interfering with the nervous system. They can act systemically or by direct contact with the pest, and most are residual. Overuse has led to many pests becoming resistant to these chemicals.

- Dimethoate (Rogor®) is a broad-spectrum systemic insecticide, particularly for sucking insects. It is highly toxic to bees. Use of this chemical is restricted in some jurisdictions.
- Maldison (Malathion®) is a general broad-spectrum insect control. One of the oldest and most widely used insecticides.

Organochlorines
These are highly toxic, non-selective, residual pesticides, and include DDT and dieldrin. Most of the chemicals in this group have been banned or severely restricted in most parts of the world.

Fungicides

Fungal diseases are more difficult to control than are insect pests. The organic and synthetic sprays and dusts described below will provide some control for most fungal pests.

Copper
It is sold in a variety of forms, including Bordeaux (a mixture of copper sulfate and lime) and copper oxychloride. It is used on a wide variety of vines, fruit trees and other plants and is usually applied to leaves and/or stems before infection is likely to occur. This provides a protective chemical barrier against both fungal and bacterial diseases. Copper can cause soil toxicity problems. Copper compounds can also damage the leaves of some plants and withholding periods should be observed.

Sulfur
Sulfur-based products are registered and approved as organic fungicides. It comes in a variety of forms including wettable sulfur, lime-sulfur and sulfur dust and acts to protect leaves with a chemical coating. It can also control established fungal infections such as powdery mildew. Not suitable for use in hot weather.

Potassium permanganate
Also known as Condy's crystals, it is used as a spray for control of powdery mildew.

Teas
Various products can be used to make non-residual organic fungicide sprays. They include garlic, chives, horseradish, nettles and milk. These products have been successfully used by many horticultural producers.

Carbamates
These compounds are non-selective and persistent in the environment.

Dithane (Mancozeb®)
This is a contact fungicide that is effective against a wide range of foliar diseases. It is toxic to fish.

Zineb
Used as a protective spray, it controls a range of fungal diseases, including rusts and mildews.

Thiram/Ziram
These are broad-spectrum non-systemic fungicides, sometimes used as seed treatments or for general protection. Not to be used in very hot or cold weather. May cause skin irritations.

Benzimidazoles
These systemic fungicides control a range of fungal diseases and in most cases the entire plant must be covered for the chemical to be effective. In some areas, fungal resistance to the chemicals has rendered them ineffective.

Benomyl (Benlate®) is a broad-spectrum systemic fungicide, particularly used for damping off (rhizoctonia) and powdery mildews. Used for soil/media drenches, foliar sprays and dusting seeds. Use gloves and do not get the chemical on your skin, as it can cause long-term health problems.

Soil fungicides
These are residual chemicals applied to the soil to prevent fungal diseases developing.

Furalaxyl (Fongarid) is effective against some soil-borne fungal diseases such as pythium and phytophthora. It has systemic and residual properties. It can be used as a drench for seed trays or dusted directly onto seeds.

Figure 7.5: A residual fungicide that can be used against some soil-borne fungal diseases.

Minimising chemical use

Nurseries can reduce their use of chemicals by applying them only when a problem arises, but this technique will work **only** if there are routine inspections of plants to determine whether problems are developing and require attention. A nurseryperson needs to be expert at diagnosing problems if this approach is to be successful, so it may involve spending more on wages to employ more competent staff or provide suitable training. However, that expense can be offset by savings on chemicals.

In many cases the amount of chemicals used to control pests and diseases can be significantly reduced by:

- correct identification of the problem;
- correct timing of applications, ensuring that the chemical is supplied when it will be most effective;
- using the most efficient application methods, thereby minimising the amount of chemical required and ensuring it most effectively reaches the problem area;
- careful selection of the chemical/s to be used.

Weed control

Weed control in a nursery is very important for the following reasons:

- to remove plants that will compete for space, water and/or nutrients with nursery stock;
- to remove plants that may act as hosts or attractants to pests and diseases;
- to remove plants that may be hazardous to staff and customers, for example by causing allergies or having thorns or poisonous parts;
- to reduce the risk of fire;
- to create a tidy appearance;
- to prevent the potential introduction of undesirable plants to new areas.

Non-chemical weed control

A herbicide is a plant-toxic chemical, therefore the use of herbicides should be kept to a minimum in places where plants are being grown. Common non-chemical weed control methods for use in nurseries include the following.

Hand-weeding

This is time-consuming but useful for small infestations, or when there is major concern about the likelihood of spray damage to plants. Hand-weeding should be incorporated into any checking of nursery crops and the surrounding areas.

Mowing/slashing

Mowers, slashers and brushcutters are very effective means of reducing unwanted plant growth. This method is good for large areas, particularly if you don't need to totally kill the unwanted plants, and for people concerned about using chemicals. This involves regularly cutting the tops from the weeds.

Sterilisation
See the section on soil sterilisation earlier in this chapter.

Burning
Flame-throwers are used by some government bodies and property-owners for killing weeds on boundary fences, or large clumps of weeds such as blackberries. Care should be taken with them as they can generate considerable heat and can damage other plants, as well as causing nasty burns to the operator. Fire should be used only by skilled operators, and never in an area where there is danger of a bushfire. It is vital to ask your local fire brigade for advice, and to find out whether burning-off restrictions are in force.

Hot water
This environmentally friendly method involves spraying extremely hot water onto weeds. This is now widely used by many local governments throughout Australia as a non-residual weed control method.

Chemical control of weeds

Chemical weed control became possible at the beginning of the twentieth century with the development of purified toxic chemicals. During the 1940s selective herbicides were developed and today herbicides come in a range of products of varying toxicity. Since the 1970s there has been a steady increase in herbicide tolerance and resistance, due to continual use of chemically similar herbicides. It has also become obvious that herbicide reliance requires ongoing use, without reducing the problem. Herbicides should be used in conjunction with other weed control methods.

Herbicides can be liquid or granular preparations, applied to foliage, stems or the soil. Their action can be systemic or contact, and they can be residual or non-residual in the environment. Most herbicides are non-selective and kill most plants they contact.

Herbicides can present a significant danger to non-target organisms. In particular, residual and foliar applications have the potential to kill desired plants, poison animals, reduce soil micro-organisms, evaporate into the atmosphere and enter the water table.

When using a new herbicide, one that you are not familiar with or in a new situation, it is worth doing a trial application on a small section of the area. This allows you to gauge results before doing a full-scale application.

The following is a not an exhaustive list, but a guide to the most common herbicides used in nurseries. Many of these compounds are highly toxic and, if used incorrectly, can harm humans, livestock, soil and waterways. If you have any doubt about the use of these chemicals, consult your supplier or the regulatory authority in your state or territory. Always read the label before use.

Iron sulfate
A traditional control method for liverworts and mosses is the use of iron sulfate sprays or drenches. Sprinkling a layer of coarse sand over the surface of a pot will keep the surface dry and reduce these problems.

Contact herbicides
These include the non-selective, non-residual compounds suitable for general

knockdown weed control in outdoor areas. These herbicides must be applied evenly to the target plant to be fully effective. They are poisonous if inhaled or swallowed.

- Diquat/Paraquat are suitable for most grasses and non-woody broad-leafed weeds. Apply when weeds along paths, roads, fencelines etc. are becoming a problem. Do not let weeds get to the seeding stage before application.

Systemic herbicides

Systemic herbicides act by entering the vascular system of plants. Not usually suitable for indoor use, spray shields may be necessary to stop drift onto nursery stock.

- Glyphosate (e.g. Roundup®), sold under a range of brand names, it is a systemic, non-residual and non-selective herbicide spray used widely around the world. Although systemic, it will not eradicate many plants with bulbs or other food storage mechanisms. It acts by interfering with enzyme activity in plants. Because there is no equivalent enzyme activity in animals, it is considered safe for use. Recently some weeds have begun to develop resistance.

Selective herbicides

These chemicals are systemic and poison only one type of plant, either broad-leafed weeds or grassy weeds. This means they can be sprayed on crops with unsuitable foliage. Some of these chemicals, including MCPA and 2,4,D, act by interfering with hormone activity in plants (and animals). They are highly toxic and residual in the environment. Many of these chemicals are now either banned or strictly controlled.

- Fluazifop-butyl (e.g. Fusilade®) can be very effective in controlling many established annual and perennial grasses in nursery stock without affecting most broad-leafed plants (shrubs and trees). Lists of plants to avoid spraying with fluazifop-butyl can be obtained from the manufacturer. It is most effective sprayed when weeds are actively growing.

Residual herbicides

These systemic herbicides are applied to the soil to prevent weed seeds germinating, usually during cultivation or irrigation. Used mainly for controlling weeds in nursery stock, they have long-term persistence in the soil and are likely to enter the water table after periods of heavy rain. With all these chemicals, contact with plant foliage should be avoided. When using these chemicals indoors, it is preferable to use granular treatments if available.

- Simazine is excellent for use near non-sensitive ornamental species, although mosses and liverworts are not controlled well at low dosage rates. Simazine may be used for pretreatment prior to bringing plants into enclosed growing areas. Golden foliage plants may be damaged by simazine applications. Other plants sensitive to simazine include fuchsia, hebe, hibiscus, lavender, hydrangea and laburnum. Lists of plants to avoid spraying with simazine can be obtained from the manufacturer.

- Oxadiazon (e.g. Ronstar®) is used widely in granular form for container weed control. Uniform application is essential – use an applicator if necessary. One application soon after potting will give 3–4 months' weed control. Some plants are susceptible to damage, including hydrangea, azalea, erica, cotoneaster, berberis, forsythia, vinca and spiraea. Lists of plants to avoid spraying with oxadiazon can be obtained from the manufacturer.

Woody weed herbicides
For persistent broad-leafed weeds such as blackberries and trees, it may be necessary to use stronger chemicals. These chemicals are non-selective and systemic and can be sprayed or injected into the wood. Examples include amitrole (Weedazole®) and triclopyr (Garlon®). In many areas, the purchase and use of these chemicals is restricted to licensed operators.

Herbicide additives

Dyes
Non-toxic coloured dyes such as food dyes are sometimes added to herbicide sprays. This reduces wastage by allowing the operator to see where they have already sprayed. It also warns visitors that herbicide has been used in the area.

Surfactants
These are additives that help keep the herbicide mixture on the surface of the plant leaf. They include soaps (beware – soapsuds can block spraying equipment) and various commercial preparations.

Figure 7.6: Commercial dyes such as this herbicide dye can be added to chemicals to allow the user to see which areas have been treated.

Noxious weeds

In all states of Australia and in many other parts of the world, there are laws covering the control of declared noxious weeds. Noxious weeds are those that present a serious threat to agriculture, horticulture, the natural environment and waterways. All landholders should be aware of the noxious weeds in their area. After weeds are declared noxious by the local department of agriculture, it is the responsibility of landholders to eradicate any noxious weeds on their property. Failure to do so can result in serious penalties.

Using chemicals

Always use the least hazardous chemical available, and follow the application rates and safety instructions on the label. Other guidelines for safe use are:

- use chemicals only when actually needed;
- use the correct chemical for the job at hand, if unsure seek advice;
- always read the label and any product information sheets;
- use protective clothing at all times;
- use the correct pesticide application equipment;
- do not spray on windy or very hot days;
- warn other people in the area that you are going to spray and have sprayed;
- wash all spray equipment thoroughly when finished;
- do not eat or smoke while spraying;
- wash all protective clothing thoroughly after spraying;
- wash yourself thoroughly after spraying, especially your hands;
- store spray equipment and chemicals in a safe locked place;
- dispose of empty pesticide containers according to the label instructions;
- record all details of your spraying.

Using chemicals inside

Applying pesticides in greenhouses presents special problems. In normal greenhouse operations employees must work inside. Space is often limited and personal contact with plants and other treated surfaces is almost a certainty. In addition, unauthorised persons may enter the premises. Ventilation is often kept to a minimum to help maintain temperatures; as a result mists, vapours and dusts may remain in the air for considerable periods.

Certain precautions should be followed to avoid problems when spraying in greenhouses:

- use full safety equipment including respirators or gasmasks, and full waterproof clothing;
- put up warning signs outside the greenhouse at all entrances. Do not enter the building without a facemask unless it has been fully aired for the length of time recommended on the chemical container label;

Figure 7.7: All staff who use chemical herbicides and pesticides must be given appropriate safety equipment and be advised on procedures to follow when spills and accidents occur.

- all possible skin contact with treated plants should be avoided by workers and others, to minimise absorption of dangerous chemicals or skin irritants;
- spray at a time when it will be possible to mostly avoid entering the greenhouse for 1–2 days after the spraying.

Forced-convection, low-volume sprayers

These are spray machines which can break chemical solutions down into smaller droplets, and thus reduce the total quantity of chemical used. Chemical and labour costs can be reduced and, by using less chemical, the environment is less likely to be polluted and the nursery sprayer is less likely to be affected. However, because the droplets are smaller they can drift more. These sprayers are thus better used in confined spaces such as a greenhouse, rather than in open spaces.

Keeping records

Records of pesticide usage are very important, particularly when using weedkillers. The record will help nursery staff to:

- improve pest control practices and avoid unnecessary pesticide use;
- compare applications made with results achieved;
- purchase only the amounts of pesticides needed;
- reduce inventory carryover;
- when errors occur, help establish where they were made;
- establish proof that you used recommended procedures if indemnity payments are involved.

When conducting a spray program, the following information should be recorded:

- varieties of plants treated;
- pests and weeds treated;
- location and size of area being treated;
- time of day, date and year;
- type of equipment used;
- pesticide used including name, type of formulation, trade name, manufacturer and batch number;
- amount used per hectare or per 100 L of water;
- amount of active constituent (chemical) per hectare or per 100 L water;
- stage of plant development (size of pot and size of plant);
- pest/weed situation, for example severe or mild;
- weather, temperature, wind, rainfall etc.;
- whether the chemical was watered-in afterwards;
- results of application. For example, how long before pests/weeds died, and how well the control agent worked.

8

Growing media

The health of all plants, whether containerised or field-grown, is largely dependent on the physical and chemical properties of the growing media used. To ensure that plants grow at their best, nurseries should use only the best-quality soil and materials. Nurseries growing plants in the open ground should apply care and attention to preparing the soil and maintaining it in optimum condition. Nurseries growing containerised stock should ensure that the growing media is formulated to suit the particular plants' needs.

To ensure healthy plant growth, nursery operators must have a basic knowledge and understanding of:

- the properties and components of soils and media;
- the nutrient requirements of plants;
- the role of pH in nutrient uptake and the healthy growth of individual plant species.

Understanding soils

Soil provides plants with the following:

- nutrition – the plant derives much of its food from nutrients in the soil;
- support – the soil holds the plant firm and stops it falling over;
- water and air – the roots absorb both water and air, and the soil must contain both. Soil with too much air leaves the plant starved for water. A soil with too much water leaves the plant starved for air.

Soils vary with respect to these factors. For example, a sandy soil provides less support than a clayey soil. A clayey soil generally provides less air than sand but has a greater capacity to hold water. An organic soil usually has a good ability to hold water, but doesn't always provide good support.

Soil is made up of organic particles that were once living (i.e. plants and animals) and inorganic particles that were once rocks, which have broken down through chemical and physical weathering. As soils play such an important role in the health and growth of plants, you should be aware of the three vital soil characteristics: texture, structure and porosity.

Figure 8.1: Soils vary in texture, structure, porosity and many other factors such as nutrient content. These soil piles have been stockpiled for potting mix production.

Soil texture

Sand, loam and clay describe the texture of a soil. The type of material that makes up a soil affects the movement of water and air through soil, the root penetration into the soil and the looseness and workability of the soil.

Components

The soil profile comprises the various horizontal layers of a soil. Each soil layer may contain soils of different textures. Soils are not evenly made up of individual particles of sand, silt, clay and humus. These individual particles are found in groups called crumbs or aggregates, throughout the soil. You can see these crumbs or aggregates when you sift soil through your fingers. The individual particles in the soil (sand, silt, clay and humus) hold together more firmly than the various aggregates (groups of sand, silt, clay and humus). Aggregates come in different shapes and sizes and are arranged in different ways to give soils their characteristic structures. Soil aggregates may include the following:

- gravel – particles larger than 2 mm;
- sand – particles 0.02–2 mm in diameter;

- silt – 0.02–0.002 mm in diameter;
- colloids – less than 0.002 mm in diameter (these are either clay or organic).

Soil also includes a certain amount of organic matter.

Colloid particles are small enough to disperse in water. Improving the soil structure has the effect of flocculating the particles (clumping the particles together).

Texture can be classified into seven classes and sixteen grades. Table 8.1 gives examples of the various classifications. The last word in a classification indicates the dominant component of the soil (loam is an equal % of sand, silt and clay).

Table 8.1: Classification of soil texture

Soil	% clay
Sand	<10%, commonly <5%
Loamy sand	5–10%
Clayey sand	5–10%
Sandy loam	10–15%
Light sandy clay loam	15–20%
Loam	25%
Silt loam	25% clay, 25% silt or more
Sandy clay loam	20–30%
Clay loam	30–35%
Silty clay loam	30–35% clay, 25% or more silt
Sandy clay	35–40%
Silty clay	35–40% clay, 25% or more silt
Light clay	35–40%
Light medium clay	40–45%
Medium clay	45–50%
Heavy clay	50% or more

Percolation rates

The rate of water percolation is another way to describe the texture of soil. Percolation is the natural movement of water through the soil, and soils percolate water at different rates. Soil should be watered only as much and as fast as can be absorbed without runoff.

Sandy soil absorbs more than 5 cm (2") of water per hour. It is very porous, with large spaces between soil particles. Little water is retained; sandy soil dries out quickly.

Loam soil absorbs 6–50 mm (0.25–2") per hour. The soil is loose and porous and holds water quite well.

Clay soil absorbs less than 6 mm (0.25") of water per hour. Clay soil is dense with few air spaces between particles and holds water so tightly that little water is available for plants.

Soil structure

Soil structure is described according to shape, size and grade (soil strength and degree of development).

Good structure in a soil means that its mineral particles are bound together in crumbs (known as peds) of various sizes, which are loosely arranged into larger groupings. This gives a well-structured (friable) soil its crumbly feel or appearance. This provides plenty of pore spaces between crumbs, allowing good water penetration, aeration and ease of penetration for plant roots and other soil life.

Crumb formation can be enhanced in a number of ways:

- the addition of organic matter;
- the addition of clay in low-clay soils;
- the addition of iron and aluminium (for soils low in these elements);
- the addition of exchangeable calcium (usually applied as lime or gypsum).

Crumb formation is reduced with increasing levels of exchangeable sodium, which is common in areas with increasing salinity problems. For example, leached clay soils which are high in sodium tend to have poor structure. Soil structure can also be readily damaged by overcultivation or poor cultivation techniques (particularly when the soil is very wet), compaction (e.g. repeated trafficking of machinery), and by killing soil life with repeated applications of chemicals.

A well-structured soil has aggregates arranged so that the soil is resistant to crushing (compaction). There should be many spaces and channels (pores) between the aggregates to allow oxygen to reach roots and movement of excess water (drainage) through the soil.

Table 8.2 gives a diagnosis of soil type depending on how it feels between your fingers.

Table 8.2: Diagnosis of soil type

	Does the soil stain your fingers?	Does the soil bind together?	Does the soil feel gritty?	Does the soil feel silky or sticky?	Does the soil make water cloudy?
Sand	No	No	Yes	No	No
Sandy loam	No	Yes	Yes	No	No
Loam (or silt)	No	Yes	No	No	No
Clay loam	Yes	Yes	No	No	Yes
Clay	Yes	Yes	No	Yes	Yes

Organic soils are soils containing a large proportion (more than 25%) of organic matter. These are usually black or brown in colour and feel silky. It is possible to get organic types of all of the above soils. A simple test of the organic matter content of a soil involves putting a small amount in a container of water. Organic matter tends to float to the soil surface, so the more material that floats, the higher the organic matter content.

Pore space in soils and growing media

Aeration and drainage in a growing media mostly depends on the amount of pore space available. The pore space can be defined as the percentage of volume that is not filled with solids. For example, a total pore space of 50% means that in every litre of media there is 50% pore space and 50% solids. Total pore space can vary from as low as 30% in a heavily compacted soil, up to 95% in some peat. Good garden soils contain about 50%

total pore space; good potting mixes and propagating media may have 60–80% total pore space.

Pore shape and size are also important. Large round or irregularly shaped particles result in bigger air spaces than flat or small particles. Large pore spaces allow greater movement of air and water. However, if the growing media has only large pore spaces, its water-holding capacity will be poor. The ideal is a combination of small and large pore spaces that provide good aeration and drainage but sufficient water-holding capacity.

Soil temperature

The rate of absorption of water and nutrients is affected by the soil's temperature. Too much heat or cold will slow the whole metabolism. Soil temperature is not always the same as atmospheric temperature. Mulching a plant or adding organic matter to the soil will even out (or lessen) the fluctuations in soil temperature. As with most organisms, plant roots will grow within a particular range of tolerance which varies between species.

Soil pH

In simple terms, soil pH can be described as a measure of the relative proportions of positive and negative ions in the soil. In pure water they are equal, and so the pH of water is normally 7 – neutral. A scale of 0–14 (pH scale) is used to record measurement of pH.

0 ———— Acid ———— 7 ———— Alkaline ———— 14

Most plants prefer a pH of 6–6.5 (slightly acid), although there are many exceptions. Plants may grow outside their ideal pH range, but they will not grow as well. If the pH is below 4.5 or above 8 it is very bad for the vast majority of plants. You should check the pH preferences of individual plants and the pH of the soil into which they are to be planted before adjusting the pH or planting.

Soil pH can be adjusted by chemicals known as soil ameliorants (soil additives used to improve soil characteristics). These include lime (to raise pH) and sulfate (to lower pH). However, the soil will tend to buffer (modify) the effect of these chemicals, so calculation of the amounts required is often difficult. The general rule is to apply small amounts until the required result is obtained – better too little than too much!

When lime is added to break up hard clay soils, it will also raise the pH of the soil and make it more alkaline. Addition of organic matter such as manure or compost, which contains weak acids, will cause the pH to drop. Fresh manure can cause a drastic drop in pH. Sulfate of ammonia will also lower pH. Some examples of the effect of ameliorants include:

- in sandy soil, 1 kg (2.2 lb) of lime dug in to a depth of 15 cm (6") over 10 sq m (12 sq yards) will raise pH from 4.5 to 5.5;
- in loam, 2.5 kg (5.5 lb) is needed to do the same;
- in clay, 4.5 kg (10 lb) is needed to do the same;
- 800 g (1.75 lb) of powdered sulfur cultivated over 10 sq m (12 sq yards) to a depth of 20 cm (8") in sandy soil will lower pH from 7.5 to 7;
- in loam, 2.4 kg (5.25 lb) is needed to do the same.

Soil testing and sampling

Soil sampling

The soil sample to be analysed should be representative of the area. Soils under intensive use in gardens, nurseries or orchards should be tested before planting a crop.

Sampling in greenhouses

1. Take samples from soil mix stockpiles before adding fertiliser.
2. Take samples from soil in beds prior to seeding or planting.
3. For soil from pots, take samples from top and bottom of several different pots.
4. Use a soil auger, corer or similar device to ensure a sample across the total profile of the soil.
5. Wait at least 6 hours after watering or rain before taking a sample.
6. If dry fertiliser has been used, wait at least 5 days after application before sampling.
7. If liquid fertiliser has been used, wait at least 24 hours before sampling.
8. Remove mulch from surface and the top 5 mm (0.2") before sampling.
9. Take 10–15 cores to provide at least 650 mL (0.14 gallons) of soil sample.

Conducting soil tests allows the nursery manager to:

- recognise various soil textures by sight and feel;
- determine the main soil texture groups;
- determine the proportion of sand, sandy loam, loam, clay loam and clay in soils;
- determine the moisture-holding properties of the various soil types;
- determine the aeration capacities of various soil types;
- determine soil pH.

The simplest soil test is to squeeze a handful of moist but not muddy soil in your hand, then rub the soil between your fingers. Take note of the following:

- sandy soils do not stick together and are coarse, gritty and loose. They won't form a ball, and fall apart when rubbed between the fingers;
- loams hold their shape but will fall apart easily if squeezed further. Loam soil is smooth, slick, partially gritty and sticky, and forms a ball that crumbles easily. It is a combination of sand and clay particles;
- clays form a plastic, sticky ball. Clay soil is smooth, sticky, and feels somewhat plastic. It forms ribbons when pressed between fingers. Clay soil requires more pressure than loam soil to form a ball.

Laboratory testing of soils

There are many sophisticated tests which can be carried out to determine the chemical and physical characteristics of soil. Generally, these tests require very expensive laboratory facilities beyond a normal working horticulturalist. There are, however, laboratories in most major cities that will test your soil samples, for a fee. It is generally impractical to attempt to conduct such tests yourself.

Measuring salinity

Conductivity meters are devices used to measure the salinity of water. An electrical device generates an electrical signal which travels between two electrodes. The ability of water to conduct electricity between these two electrodes is an indication of the dissolved salt: if the electric current flows more, there will be more dissolved salt, meaning that there are more nutrients – or more fertiliser – in the soil. Low electroconductivity (EC) readings indicate that the soil needs fertilising. High EC readings can indicate toxic levels of nutrients. An EC meter is one of the least expensive items of soil-testing equipment, costing $200–300.

Figure 8.2: A soil EC (electroconductivity) meter.

Methods of measuring pH

Probe meters

Probe meters comprise a probe on top of which is mounted a small meter sensitive to electric currents. The probe is simply pushed into the wet medium and the pH read on the meter. These instruments are very unreliable and their use is not recommended.

Colorimetric methods

In these methods, the colour obtained when the soil is mixed with an indicator solution is compared with those on a colour chart, to give the pH. There are kits available to carry out these measurements. They are cheap and reliable and give results accurate enough for most landscaping and garden situations. Colorimetric tests can be used for quick screening and checking in nurseries.

pH meters

Meters for reading pH consist of a electrode and an electronics system which provides a readout on a dial or a digital display. pH meters are very delicate and relatively expensive. Care must be taken in their operation and they must be calibrated with standard solutions. The measurement obtained with a pH meter depends on the method of extracting the soil solution. Saturated paste extracts are the most easily standardised method. Enough water is added to just flood the sample. The solution is then extracted and tested. The volume soil/volume water method is easier but the results can be influenced by the soil characteristics. The ratio most widely used is 1 part soil to 5 parts water.

Measuring organic matter in soil

Organic matter in soils helps to hold soil moisture as well as improving soil texture and soil fertility. The following experiment can be used to determine the amount of relatively fresh soil organic matter, and is useful in comparing the organic matter content of various soils. Carry out several experiments on various soils to determine the difference.

1 Weigh a sample of soil in a glass container. The reading is represented as w1 (weight without container).
2 Mix 6% of 30 volume hydrogen peroxide at the rate of 9 mL hydrogen peroxide to 1 g of soil.
3 Shake and then stand the sample for 24 hours until the bubbling almost ceases.
4 Add water to stop the reaction. Evaporate to dryness either in an oven at 40°C (104°F) or in the open air. Weigh. Continue to dry until the weight remains constant. The final weight reading is represented as w2.
5 Calculate organic matter percent as (w1 – w2/w1) × 100.

Improving soils

Adding organic matter

Organic matter plays an important role in the formation and stabilisation of aggregates. The roots of plants, soil micro-organisms and earthworms all help to form aggregates. Roots probably play the most important role in forming aggregates. Their movement through the soil and their expansion during growth squeezes soil particles together. The drying of a tube of soil around each root makes the soil stress and strain, which in turn causes the clay and mineral particles to line up with one another.

The importance of this interaction is clear, when you consider that the particles in stable aggregates are held together by chemical bonding of inorganic materials such as iron, aluminium oxides and silica; 'skins' of clay around the aggregates; and molecules of organic matter.

To help improve soils it is important to:

- add lots of organic matter to all soils. Use composted kitchen scraps, weeds (but not the seed heads), lawn clippings, sawdust and straw – anything that was once living and can be broken down by soil organisms;
- if your soil is sandy, add lots of decayed organic matter and cover the soil with mulch;
- if your soil is heavy clay, dig in sand and organic matter. Adding gypsum or products like Clay Breaker will help to open the soil and improve drainage;
- add earthworms to the soil, but make sure they have enough organic matter to encourage them to stay.

Improving drainage

One of the most common problems with soils in winter is poor drainage. In colder areas with overcast and damp winters it is normal for the soil to stay very moist for weeks, even months. This is an important natural process, allowing the water to penetrate deeply into the subsurface in readiness for the growth flush in the warmer spring. Have a close look at the drainage problems. Are they caused by underground seepage, surface runoff, or both? Is the whole garden affected or only some parts?

In some areas, winter is not the best time to install drains because the channels quickly fill with water and remain full for weeks, making it very difficult to actually lay the pipes.

If the problem is severe, you may need to dig an emergency channel to drain the water away, then lay the pipes when the soil dries out in spring.

Improving nutrient availability and pH

The ease with which nutrients can enter a plant is greatly affected by pH. Extremely acid or alkaline soils can stop nutrients from being absorbed and used by the plant. The plant will suffer a nutrient deficiency, not because the required nutrient is not in the soil but because the plant cannot use it (it is not available). The ideal pH for nutrient availability is different for each nutrient. To make the pH such that iron is very available means that calcium is not available. The answer is usually to compromise: go for a pH in the middle.

Table 8.3: Optimum pH for nutrients

Nitrogen	6–8
Phosphorus	6–7.5
Magnesium	7–8.5
Iron	4–6
Boron	5–7
Calcium	7–8.5
Potassium	6–10
Sulphur	6–10
Manganese	5–6.5
Copper and zinc	5–7

Potting mixes

A brief history

Various potting mixes have been used through the centuries. There has never been a perfect mix, and probably never will be. The best mix available never seems to remain available for long, because the suppliers run out of components sooner or later. This makes it necessary for nurseries to constantly review the mixes they use.

Pre 1930s

During this time, everyone seemed to have their own favoured mix. Components included such things as sharp sand, peat moss, various types of manures, leaf mould, compost, charcoal, burnt turf (sterilised loam) and scalded moss.

1939

In 1939, the John Innes Research Institute in the UK began developing a series of loam-based composts.

- Seed compost: 2 parts loam (pH 6.3), 1 part sand, 1 part peat, 1.2 kg superphosphate and 0.58 kg ground limestone per m^3.
- Potting compost: 7 parts loam, 3 parts peat, 2 parts sand, 2.9 kg superphosphate and 0.58 kg limestone per m^3.

1941

The University of California began to develop a series of mixes in 1941. The *UC System for Producing Healthy Container Grown Plants* is a book published in 1957, which outlines not only these mixes but many other basic practices used in the modern nursery. Copies are generally only available at libraries. These mixes are based on a mixture of peat and fine sand.

Table 8.4: The five main UC mixes

Mix	% fine sand	% peat	Comments
A	100	0	Seldom used, densest, in beds or trays
B	75	25	Commonly used, good physical properties, in containers, trays or beds
C	50	50	Frequently used, excellent physical properties, in containers
D	25	75	Light, excellent aeration, in pots
E	0	100	Very light weight, used for azaleas, sometimes camellias and gardenias

Fertilisers and often lime are added to the UC mixes to provide nutrients, and to adjust the pH to the appropriate level.

1970s in Australia

Soil-less mixes have become popular, largely due to the unreliability of soil components in mixes. Many nursery managers still insist upon a small soil component in their mixes, largely due to the advantageous effects of soil on plant nutrition.

Many mixes are based upon pinebark mulch, which is readily available in some parts of Australia. Bark or other timber components have the disadvantage of being contaminated with toxic chemicals when fresh. Proper composting before mixing can dispose of these chemicals, but some soil companies have been known to supply mixes which are still contaminated. Any such mixes should be tested before using. Test every delivery!

1980s in Australia

During this era, Knoxfield Research Station (in Melbourne, Australia) conducted much research on potting mixes and presented various recommendations. For example, in 1984 'The standard pine-bark potting mix recommended by Knoxfield Horticultural Research Institute is: 8 parts pine-bark, 3 parts coarse washed river sand, and 1 part brown coal (lignite)'.

Two fertiliser strategies for use with this mix, suitable for short-term container plants (6–12 months) including most indoor species, are as follows (the amounts of fertiliser are for a cubic metre of mix). The first strategy is:

- 1 kg Osmocote 3–4 month (15–5.2–12);
- 2 kg Osmocote 8–9 month (18–4.3–8.3);
- 0.5 kg GU 49 or Osmocote-coated iron;
- 0.5 kg Micromax;
- dolomite to bring pH between 5.5 and 6.0 (2 kg).

The second strategy is:

- 2.1 kg IBDU;
- 3 kg Osmocote 8–9 month (18–4.3–8.3);
- 0.5 kg GU 49 or Osmocote-coated iron;
- 0.5 kg Micromax
- dolomite to bring the pH to between 5.5 and 6.0 (2 kg).

In 1984 Kevin Handreck and Neil Black (both from Australia) published an excellent reference book called *Growing Media for Ornamental Plants and Turf*. This comprehensive and practical text is probably one of the most useful references for a nurseryperson.

Other potting mixes

Cornell Peat-Lite mixes

This mix produces a lightweight, uniform soil-less media which has chemical and physical characteristics suitable for plant growth. It does not need any sterilisation.

Peat-Lite mix A – to make 0.76 m^3 (1 cubic yard):

- 0.39 m^3 shredded sphagnum peat moss;
- 0.39 m^3 horticultural grade vermiculite;
- 2.25 kg grounded dolomite limestone;
- 0.45–0.9 kg single superphosphate (20%), preferably powdered;
- 0.45 kg calcium nitrate;
- 84 g fritted trace elements;
- 56 g iron sequestrene (330);
- 84 g wetting agent.

Peat-Lite mix B is the same as mix A, except that horticultural perlite is substituted for vermiculite.

Peat-Lite mix C – for germinating seeds:

- 0.035 m^3 shredded sphagnum peat moss;
- 0.035 m^3 number 4 horticultural vermiculite;
- 42 g ammonium nitrate;
- 42 g superphosphate (20%), powdered;
- 210 g ground dolomite limestone.

The addition of slow-release fertilisers is beneficial if plants are grown in the mix for extended periods.

Other soil potting mixes that may be worth trying include:

- heavy soils, such as clay loams – 1 part soil, 2 parts perlite or sand, 2 parts peat moss;
- medium soils, such as silt loams – 1 part soil, 1 part perlite or sand, 1 part peat moss;
- light soils, such as sandy loams – 1 part soil, 1 part peat moss.

For each 35 L of these mixes, add:

- 224 g dolomitic limestone (to provide lime, calcium and magnesium); for acid-loving plants use calcium sulfate as a substitute;
- 280 g superphosphate (20%) (to provide phosphorus and sulfur).

(Hartmann et al. 2002, *Plant Propagation*, 3rd edn).

Components of potting mixes

So that plants achieve optimum growth a potting mix should have a balance between aeration and water-retaining abilities; preferably it should have at least 15% air space. The most common components in a nursery mix today are sand, soil, bark and peat. 80% of the mix is usually softwood bark with 10% peat added to improve water retention. The sand and soil component is included to add weight to the mix, improving stability of containers.

Sand has good water-holding capabilities and, when added to pinebark it slows the rate of water infiltration rate through the container. However, adding sand to the mix also reduces the air space and total porosity so you must be careful not to reduce the air space too much in mixes containing sand, particularly when plants are overwatered – the total air space in pots is reduced when the sand is wet and increased as the sand dries out. Anoxia of the root system can occur in waterlogged pots.

Although the above components are most predominantly used in potting media, alternative materials include coir fibre (made from shredded coconut husks), composted animal manures, mushroom compost, composted hardwood bark, rice hulls and peanut shells. Organic components tend to decompose rapidly, which can lead to once-full pots being much emptier in a short time. Animal manures have high soluble salts and nutrient levels so should be limited to 10–30% of the mix. Peat moss and pinebark will lower the pH level of a mix to 5.0–6.0, even with dolomite lime added. Mushroom compost added to a mix will result in a higher pH of 6.0–6.5, so it is not necessary to add lime.

Figure 8.3: A garden mix guaranteed to be free of weed seeds. When buying growing media, check its components and whether it is backed by any regulatory organisation such as Standards Australia.

Soil

Soil is still occasionally used in potting mixes as a minor component, usually less than 10%. Some advantages of using soil are that it may be easy to obtain locally; it adds mainly organic weight to the mix; it is well-buffered so pH changes are slow to happen; and it does not have the complicated chemical toxicity problems which can occur in soil-less mixes. For these reasons, including some soil can be helpful even in a predominantly soil-less mix. Some problems are that many pests and diseases are mainly soil-borne, so soil-less mixes generally have fewer such problems; soils can be contaminated with weed seeds; and it may be difficult to find a reliable soil supply with known characteristics.

Sand

Sand is more commonly a component of propagating mixes and is sometimes used in potting mixes as well. It is used to improve drainage and to add weight to the containers, but rarely comprises more than 10% of the total mix. Granitic or silica type sands should be used. Calcareous sands are very alkaline and unsuited to plant growth. Beach sand is not suitable because of its high levels of salt. Some sands include a lot of dust or other fine material when purchased, which need to be washed out before the sand is used. The ideal sand is coarse granite sand. This is the sand used by nursery managers for plant propagation and is often used in fish aquariums.

Sand is generally close to inert, and has no effect on chemical balance of the overall mix. Therefore it is often mixed with other water-retaining materials, such as peat or vermiculite, to obtain a balanced media, and can be added to mixes to improve drainage and aeration. Also, supply of sands with known characteristics is more reliable than for many other components. On the other hand, sand makes pots heavier to move.

Peat

Peat moss is lightweight, porous, well-aerated and drains well. It mixes well with other components, but often requires moistening before use (if it dries out it can be difficult to wet). The pH of peat moss can be low (4.0–4.5) and mixes incorporating peat may need extra lime to offset this effect. Occasionally, some types of peat have a salt toxicity. The main disadvantage, though, is cost and the fact that it is a finite resource. Coir fibre made from coconut husks is becoming a more common alternative.

Coir

The use of coir to replace peat moss is a relatively recent development. The raw material looks like a more granular sphagnum peat. Coir can hold up to nine times its weight in water, is easier to re-wet than peat, contains significant amount of phosphorus and potassium, and because it contains more lignin but less cellulose than peat it is more resistant to microbial breakdown and therefore it shrinks less. Current research indicates that the total soluble salts (electrical conductivity), sodium and chloride levels, in coir could be a problem and should be tested before growers change to total use of this product.

Pinebark

Pinebark resists decomposition and contains less organic acids (that leach) than hardwood bark, making it a preferred product. The bark is either aged or composted. Ageing is a cheaper method but has a greater nitrogen draw-down when used for containerised plants than composted bark. Pinebark is shredded into different grades (different-sized lumps), and it frequently comprises 50–70% of the potting mixture.

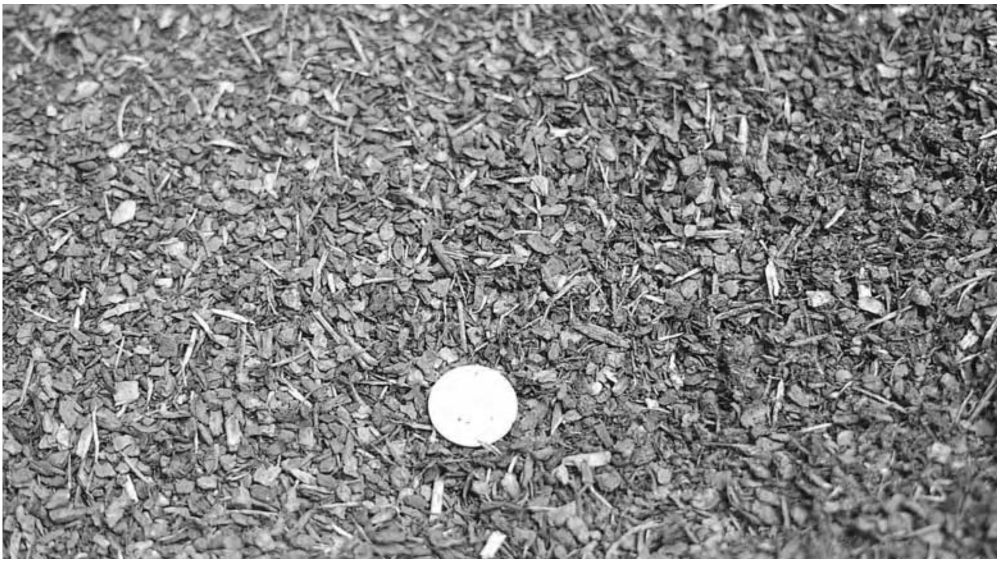

Figure 8.4: Pinebark is a common ingredient in many types of growing media. It resists decomposition and contains less organic acids than hardwood bark.

Bark which has a resinous smell or is reddish in colour should not be used unless it is very well-composted first. Fresh pinebark is toxic to plants, and requires proper composting for several months before use. Bark which has not been composted (aged bark) ties up nitrogen available to the plant. The action of micro-organisms in the decomposition of the bark uses any nitrogen which is there, so plants grown in such a mix can show nitrogen deficiency.

Sawdust

Due to its high carbon:nitrogen ratio, sawdust is not generally recommended for inclusion in potting media. It requires adequate composting and the addition of nitrogen to be suitable for use and to avoid nitrogen deficiency in plants. Like pinebark, sawdust has problems with toxins and nitrogen availability. Composting is necessary. Hardwood sawdust should be composted for 6 weeks or more, adding the following fertilisers to every cubic metre of sawdust being composted:

- 2.6 kg urea;
- 0.5 kg potassium sulfate;
- 5 kg dolomite (for a final pH of 5.5);
- 9 kg dolomite (for a final pH of 6.0);
- 8 kg dolomite (for a final pH of 6.5);
- 2 kg superphosphate (less if growing phosphorus-sensitive plants);
- trace elements might also be added in small quantities.

Lignite

Also called lignapeat, or brown coal, this substance is not coal, but is taken from coal mines. Lignite has great water holding capacity, which can be a problem in keeping the mix too wet if used in high quantities. It can also be very dusty, and will stain clothing and hands easily. The main advantage is it is cheap cost.

Figure 8.5: Sawdust can be used as a component in growing media. However, fresh sawdust tends to rob the soil of nitrogen. To alleviate this problem, sawdust should be composted or extra nitrogen added to the mix.

Coal ash

Coal ash is the material taken out of industrial furnaces and burners after black coal has been burnt. Brown coal ash is not suitable. After cooling with water, the ash is taken from the furnace, then crushed and sieved. The pH, nutrient content and other properties of the ash can vary, which affects its suitability for growing plants. Ash can also develop compaction problems over time, making it sometimes unsuitable for potting mixes. In coastal areas, ash is sometimes cooled with salt water, which leaves it contaminated and unsuitable for growing plants. However, ash sieved in a 6 mm (3/16–1/4") sieve has given excellent results as a propagating medium.

Vermiculite

This is a mineral derived from mica mined in South Africa and the US. The mined mineral is treated in a number of ways, including heating at temperatures of nearly 1100°C (2000°F) to obtain the product used in horticulture. It is sold in four grades, with #1 being the coarsest and #4 the finest. The finer grades are used for seed germination or to cover seed trays. Vermiculite is sterile, very light and spongy in appearance, and weighs about 112 kg/m^3 (7 lb/ft^3). It retains air, water and nutrients very well, making it ideal for hydroponics. The pH of vermiculite is sometimes slightly acid or slightly alkaline, although rarely enough to pose much of a problem with growth. It also holds positive-charged nutrients like potassium, magnesium and calcium.

Vermiculite should be mixed with other media to get the best results. Even though it retains air well, it can retain too much water for many plants. If used on its own, after a year or so it can turn puggy (the structure can collapse). Mixed with gravel or sand (no more than 40–50% vermiculite), puggy collapse does not happen and drainage is improved, making it a more ideal media.

Perlite

Perlite is like vermiculite, a processed mineral. It is produced by heating igneous rock to high temperatures. It has excellent water-holding properties but is less spongy and better-drained than vermiculite. Perlite is often used by itself for propagation or in a 50:50 mixture with vermiculite, although this type of mix can become too wet in some situations. Like vermiculite, it is relatively lightweight. Perlite is pH neutral, sterile, odourless and chemically inert. The source of perlite is important, as the quality varies. For example, some Australian perlite contains too much fine material. Sieved or graded perlite is generally preferred. Because perlite is predominantly white, algal growth can be a problem, and perlite can be expensive.

Expanded plastics

These materials are inert, and in many cases relatively inexpensive. Examples include polystyrene (beanbag) balls, hygropor (a mix of ureaformaldehyde and polystyrol), and polystyrol. Their major disadvantages are that they do not retain moisture or nutrient much, they are very light and, when mixed with other materials, often separate out (or float) to the top. After a couple of months' use, what was originally a mix can end up as two layers of the different materials.

Scoria

Scoria is a porous volcanic rock which can be obtained in a wide variety of grades (sizes or diameters). The physical properties of scoria are excellent, but its pH can vary greatly (pH 7–10) according to where it comes from. Scoria which has a high pH needs to be kept moist and exposed to the weather for up to 12 months to remove excess lime before it is used. It can be abrasive on soft stems, so should not be used for growing seedlings. The cost of scoria is usually dependent on the distance it has to be transported. If you are close to a scoria quarry it can be cheap; if you are some distance away it can be expensive. In Australia, scoria is freely available in parts of Victoria and north Queensland.

Leca or expanded clay

This material is made by blending and bloating clay in rotary kilns. The material is tough and forms strong balls with medium drainage and water-holding capacities. In some countries it can be very expensive. It is popular for use in waterwell type pots for indoor plants.

Rice hulls

Rice hulls are pH neutral, light and useful to increase drainage and aeration. Nitrogen needs to be included to avoid nitrogen draw-down. Once composted, the pH of rice hulls will be slightly acid (pH 5.7–6.2) and have greater water-holding capacity then uncomposted hulls.

Zeolite

Zeolite is a mineral with a high cation exchange capacity and improves nutrient retention in media. Its use in potting media is a relatively recent development, and its ability to supply nutrients in useful quantities is limited. It can be used in quantities up to 10% volume.

Others
Other components include peanut shells, spent mushroom compost, sewage sludge, blue metal, pumice and diatomite.

Choosing a potting mix

Without good-quality materials you will not grow good-quality plants. Growing media should be selected to suit the species you are growing: this is critical to the successful production of plants. Although some larger nurseries blend and formulate their own potting mixes, the purchase of pre-mixed media is common. Suppliers offer a diverse range of mixes which may incorporate materials such as lime and wetting agents as well as fertiliser. Blends, usually in large quantities, can also be specifically formulated to suit the requirements of the individual nursery.

Container plants are grown in a variety of different media. Some are mainly a mixture of soils; others are a mixture which includes no soil at all. Some potting media are combinations of soil and non-soil components. The ideal potting medium should be:

- free of weed seeds;
- free of pest or disease organisms;
- free-draining and with good aeration, but with sufficient water-holding ability to reduce watering frequency;
- able to retain sufficient nutrients and moisture for healthy plant growth;
- able to allow waste salts from fertilisers to leach out of the soil easily;
- heavy enough to make the pot stable, but light enough to minimise the effort involved in lifting;
- of consistent quality throughout, and stable over a period of time;
- cost-effective and available.

Making quality potting mix with uniform characteristics requires components which are of a very even quality (not much variation in particle size or chemical properties). Achieving this usually requires very expensive screening and mixing equipment. This means that high-quality potting mixes are generally produced only by specialist companies.

In many parts of the world, potting mix companies still operate with less-sophisticated equipment, hence produce less-sophisticated mixes which can vary in quality. Because good potting mix equipment is very expensive, the best mixes are also expensive. In Australia, high-quality potting mixes carry the Australian Standards logo.

Potting media may combine any number of different media. The availability and cost of components can vary greatly from place to place, so the things which are generally most available are normally those which are most used. Nurseries in isolated areas may have little option but to make their own mixes, but in more populated areas there are usually several large and reputable companies offering a wide variety of mixes.

Different mixes for different situations

Different types of plants have different needs. Nurseries which grow a wide variety of plants may need to use a variety of different mixes, but nurseries growing only one type of plant may be able to use just one or two types of mixes.

Some special needs of different plants and conditions are described below.

- Indoor plants – Humidity is a requirement of indoor plants. Most indoor plant mixes are high in materials that will retain moisture and promote humidity around the plants.
- Baskets – These are prone to drying out, so good basket mixes contain peat or other water-retentive material. They may also contain water crystals.
- Outdoor pots, tubs and planters – Generally, a multi-purpose potting mix will suffice for most plants. Potting mixes are high in nutrients to compensate for the fact that the plants' roots are contained in a pot.
- Acid-lovers – Acid-loving plants such as camellias, heathers, azaleas and rhododendrons are best planted in an ericaceous (acid) potting mix. While they will probably survive in a multi-purpose mix, they will grow more strongly and flower better in acid soil. If you cannot acquire an acid mix you can make your mix more acid by adding a solution such as Miracid. You can check the pH of your potting mix with a simple soil-testing kit available at your local nursery or garden centre.
- Special mixes – There are a number of special mixes available for specific plant species such as cacti and orchids.

Australian standards for potting mixes

Australian standards for potting mixes were established in the late 1980s (No. 3743-1989) and it is possible to buy packaged potting mixes that bear the Australian Standards Mark. This indicates that the mix is of excellent quality. The quality is guaranteed by regular testing both at the manufacturing plant and by independent laboratories under the supervision of Standards Australia.

There are two Australian Standard potting mix grades: regular and premium. Both mixes must be free-draining, yet capable of holding a good supply of water. Both must be easy to re-wet if they dry out. They must be free of toxins and have a pH in the range 5.3–6.5. Both mixes should contain a full range of trace elements in sufficient quantities for at least a year of plant growth, as well as ample initial amounts of phosphorus, calcium, magnesium and sulfur.

Regular mixes are not required to contain any soluble nitrogen, but the worst of their ability to draw-down fertiliser nitrogen has been removed. Premium mixes must contain soluble nitrogen and be able to continue providing enough soluble nitrogen for at least one month of good plant growth. Premium mixes generally contain slow-release fertiliser and have been made from high-quality materials such as thoroughly composted pinebark and peat.

Within both the regular and premium grades, Australian standards list properties for a range of specialist mixes for use with such plants as seedlings, orchids (cymbidium), acid-loving plants, and plants that prefer low phosphorus. Potting mixes formulated to Australian standards may appear to be more expensive than other mixes, but their reliability and quality make them less expensive in the long run.

There are also some potting mixes that state they conform to Australian standards, but which do not carry the Standards Mark. These products have not been tested by Standards Australia so there is no guarantee of mix quality. For this reason, potting mixes that carry the Standards Mark should be preferred.

The names of potting mixes that have been approved to carry the Standards Mark can be obtained by contacting Standards Australia:

286 Sussex St, Sydney NSW 2000
GPO Box 5420, Sydney NSW 2001
Telephone: +61 2 8206 6000
Email: mail@standards.org.au
Website: www.standards.org.au

Problems with potting mixes

Various problems can arise in potting media. Vigilant nursery producers will ensure that these problems are minimised by having guidelines for handling and using potting media. These guidelines should include the following.

- Only change growing media after experimenting to ensure that there will be no adverse effect on your cultural practices.
- Test media pH, its water retention qualities and total soluble salts before use.
- Ensure media is mixed thoroughly but not too much, as this can affect the vermiculite (if present) and coated fertiliser granules.
- Keep media containing fertiliser dry and use it soon, as it has a shorter storage life, particularly if it becomes damp.
- Cover media that is stored outdoors.
- Prevent contamination with additives by storing separately.
- Mix stored near growing beds should be placed higher then the beds to avoid contamination from runoff, that might spread disease to the potting media.
- Mix or components of a mix should be stored on concrete to prevent contamination by pathogens and weeds from soil.
- Fertiliser and other additives should be stored in a dry covered area.
- Keep media containing peat well-protected, as it will become water-repellent if allowed to dry out completely.
- Media should be kept moist. Steam rising from fresh media indicates loss of moisture. Once a pile is dry, it will be difficult to re-wet.
- Monitor to ensure that anaerobic pockets do not develop in the media piles, as they can have a phytotoxic effect on plants. The pH in these piles is usually low and the amount of soluble salts high.
- Check pH and electrical conductivity (soluble salts) after media is delivered, particularly if the heap is hot and steamy or you can see clouds of spores. In this instance the media should be wet thoroughly and checked for suitability in 1–2 weeks.

Water repellence
Waxy layers on organic material repel water. Therefore, some soils repel water when they are dry. For example, a mix containing a lot of peat moss will usually absorb water if wet, but if it totally dries out water may run off the surface and down the sides of the pot, leaving the rootball dry.

Water repellence can be reduced by adding sand to the mix, or applying wetting agents (synthetic surfactants). Wetting agents are similar to soaps. However, dishwashing liquids do not work for very long as they biodegrade, and many wetting agents on the market become useless after a short period. The two best Australian products (according to research by Kevin Handreck, formerly of the Australian CSIRO) are Wettasoil and Aquasoil-Wetta, both still effective after eight months.

Propagation media

No propagation method will work if you use the wrong media for growth. The ideal propagating mix will supply the correct balance of air and water to encourage the developing root system. It will anchor the cutting or seedling, hold nutrients for uptake by the growing plant, and be sterile to facilitate healthy growth. Soil or compost may harbour diseases, so are not the best choice.

The contents of media should vary for different species and cultivars, container sizes and environmental conditions, such as the watering regime and temperature. Different media may be used for propagating cuttings and for germinating seeds. Most propagating media contain combinations of sand, peat, sphagnum moss, vermiculite, perlite, compost and shredded bark/sawdust.

Properties of propagation media

Physical properties
The material or combination of materials that you use as a propagation media should have certain properties.

- The media should provide good physical support to the plants you are growing.
- The media should be reasonably light, easy to handle and easy to stick cuttings into. Sharp-edged materials, such as scoria, may be a problem for germinating seedlings.
- The materials used should not readily degrade or break down once in use.
- The media should have good aeration. This will aid water penetration and drainage, provide adequately for the exchange of gases (root absorption of oxygen and release of carbon dioxide) and provide space for roots to grow.

Air space. Once a medium is watered, the volume of pore space containing air is reduced. The percentage of a medium filled with air when just drained is commonly called its ‘air-filled porosity’ or ‘air space’. A propagation media should have an air space of at least 27% evenly spread throughout its volume. The ideal available air space will vary according to the plant you are cultivating. For example, cuttings of aerial-rooting plants require much more available air space. The provision of misting will also generally require an increase in the air space of your media. The upper limit should be no more than about 35–40%.

Air space can be simply determined by lining a propagation tray or pot with thin plastic and filling the container with moist, but not wet, propagation media to its normal level. You water the media until the water level reaches the surface of the media, then cut a hole in the bottom of the plastic so that excess water can drain away. Collect this water and measure the volume. This volume is roughly equivalent to the volume of available air space for that media in that type container. The % air space can be calculated by:

$$\frac{\text{Volume of water}}{\text{Volume of media}} \times 100$$

Particle size. The particle size of the medium is important in relation to seed germination. There must be sufficient surface contact between the seed and the particles in the propagating mix to maintain adequate seed moisture. Small seeds in a mix containing large particles will tend to dry out between watering. The larger the seed, the less critical the particle size. A mixture of particles ranging in size from 1–5 mm (up to 0.2"), with the addition of very fine particles from materials such as peat or pinebark, generally provides a suitable mix.

Chemical properties

Propagation media should have the following chemical properties.

- It should be chemically stable during use.
- Most plants require media with a pH in the range of 4.0–6.0 (some will do better at a higher pH). pH can be increased by the addition of lime, and decreased by increasing the percentage of materials with low pH such as peat moss and pinebark.
- Media should be low in salts or other harmful chemicals.

Biological properties

The propagation media should be as free as possible of harmful organisms such as weed seeds, spores and insects.

Mixes/substrates for starting cuttings or seeds

The commonly used mixes are as follows:

- Sand and peat – Normally 75% coarse washed sand to 25% shredded peat moss. In some cases, proportions can vary to 100% peat for fern spore, and up to 90% sand under continuous mist systems.
- Sand and perlite – Normally 50:50 mix.
- Peat and perlite – Normally 10% peat to 90% perlite. Sometimes straight perlite.
- Vermiculite and sand – Normally 75% sand to 25% vermiculite. Never more than 40% vermiculite.
- Rockwool – Material made by spinning fibres of molten rock. Only use horticultural grades. Has great ability to hold both air and water (it is only 3% solids). Not widely used, but very promising.

- Polystyrene and peat – Normally 50:50. Polystyrene must be mixed only with lightweight material such as peat.

Nutrient elements

Research has shown at least fifty different elements may be used by plants, although this does not mean that all of these are necessary to all plants. The elements usually considered necessary to the life of all plants include carbon (C), oxygen (O) and hydrogen (H), as these elements are the basis of all organic molecules.

Elements required by plants are generally divided into two groups: the major elements or 'macronutrients', and the minor elements or 'micronutrients'.

The six macronutrients are nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium(Ca) and sulfur (S). Plants need these in much larger quantities than any other elements (except carbon, oxygen and hydrogen). Most soils have ample supplies of calcium and magnesium; hence fertilisers which are used in horticulture are usually largely made up of nitrogen, phosphorus and potassium foods. The exception is hydroponics, where large amounts of magnesium and calcium must be added.

The micronutrients (trace elements) are all those elements taken up by plants in only small amounts. They include iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo) and chlorine (Cl). The number and importance of trace elements will vary according to the type of plant and the use to which they are put. Some micronutrients, such as cobalt (Co), chromium (Cr) and iodine (I), are more important for human nutrition than for the plant. Other elements are needed only by certain types of plants, or their requirements are uncertain. These include sodium (Na), aluminium (Al), silicon (Si) and selenium (Se).

We could include a third group of elements: those non-toxic elements that are taken up but not required by plants. This group could be very large, including even gold (Au), but is of no importance to our discussion here.

For all elements there are generally only two routes of entry into the plant – air and water. Carbon and oxygen are obtained mostly from the air. As these elements are required by all parts of the plant, the roots rely heavily on the 'soil air' for their supply of oxygen. Thus, the so-called condition of waterlogging is really more a form of suffocation. The soil is so saturated with water that the roots can no longer obtain the oxygen they require. All other elements enter the plant dissolved in water, which is generally taken up by the roots from the soil or other growth medium. However, the plant also has a certain capacity for nutrient uptake from solutions sprayed onto the leaves.

Major elements

Nitrogen

This element is essential for good foliage and stem growth. When there is a flush of rapid growth, nitrogen requirements become particularly high. Adequate nitrogen is essential for good fruiting and other plant processes, as it is required in the synthesis of proteins and enzymes in every living cell, though it is more closely related to the green growth.

Nitrogen is obtained via the roots from the soil solution (legumes also obtain it from the atmosphere). Good sources of nitrogen include sulfate of ammonia, blood and bone, sodium nitrate, calcium nitrate, potassium nitrate, urea and most manures.

Nitrogen fertilisers are applied to plants to stimulate green or vegetative growth. Obvious situations that require nitrogen include:

- on leafy vegetables or on young plants to stimulate faster growth;
- on lawns to make them greener;
- on plants grown for their foliage.

Symptoms of deficiency include stunted growth and general chlorosis, while toxicity is generally first noticed by a lush green overgrowth, with increased susceptibility to frosts etc. and eventual collapse.

Phosphorus

Adequate phosphorus is essential to maximise root development for growth and energy transfer. Deficiencies lead to poor fruiting and spindly growth. Other symptoms may include purplish tinting of leaves and poor seed set. Lack of phosphorus is common in Australian soils, making it essential to fertilise well with phosphorus to achieve good growth in many types of crop. Good sources of phosphorus include superphosphate, monocalcium phosphate, shrimp waste, raw sugar waste, bone meal and other organic foods (including blood and bone).

Remember, however, that only about 20% of any amount of phosphorus applied to the soil may be immediately available to the plant, the rest being released slowly over a period of time. Some Australian native plants, such as grevilleas, have adapted so well to low-phosphorus soils that they can easily be harmed by fertilising with phosphorous.

Potassium

Plants require quite large amounts of potassium to maintain cell turgor and the plants' water relations, controlling the opening of stomata etc. Soils in dry areas usually have good reserves of potassium. It is very soluble and very mobile in the plant. Good sources of potassium are potassium sulfate (sulfate of potash), potassium chloride (muriate of potash), wood ash and organic fertilisers (seaweed, straw and most manures).

Figure 8.6: Liquid seaweed fertilisers are an excellent source of trace nutrients.

Good levels of potassium are needed for flowering and fruiting, in particular. It is also very active in meristematic tissue, where it appears to behave in a similar way to calcium. Deficiency symptoms include marginal chlorosis of older leaves, low yields, weak stems and meristematic necrosis.

Magnesium
This element is essential to chlorophyll (green pigment) formation and energy transfer processes. Developing fruit also have a high magnesium requirement. Deficiencies are usually noted by intervenal chlorosis (yellowing between the veins) and stunting. Good sources of magnesium include dolamitic limestone (dolomite) and epsom salts.

Calcium
The main role of calcium is to help stiffen or give support to foliage. Good sources include slaked lime, agricultural limestone, dolomite and gypsum.

Calcium is not transportable in the phloem, where it is rapidly precipitated as calcium oxalate. Thus, symptoms of deficiency appear in growing foliage and shoots as chlorosis (yellowing) of young shoots and leaves at the tips or margins, as well as in developing fruits.

Sulfur
This element is not often deficient, as many forms of fertiliser are provided as sulfates. Also, toxicity is rare due to high tolerances in many plants. This, along with their solubility, is why sulfates are used in fertilisers. Sulfur is, however, very necessary for plant growth, and a plant may require almost as much sulfur as it does magnesium. One of its main functions in the cell is the formation of disulfide bonds involved in forming protein molecules. When deficiency occurs it is usually noticed as chlorosis (yellowing) of the leaf veins (as opposed to the intervenal chlorosis of other nutrients).

Minor elements

Many minor elements are as critical as the major elements, but are required in smaller quantities. Deficiency of a minor element, however, can have just as devastating results as deficiency of a major one.

Iron
Iron is essential for the functioning of a number of pigments used to give green colouring to plants (cytochromes etc.). Lack of the small amount of required iron will cause plant growth to stop and produce intervenal chlorosis in many plants. Iron deficiencies are more common than any other minor nutrient problem. Plants which commonly suffer iron deficiencies include banksias, proteas, grevilleas, citrus, azaleas and daphne. Suitable fertilisers are iron chelate, iron sulfate or even some old rusty nails.

Zinc
This element contributes to the manufacture of carbohydrates and proteins, by functioning as an activator of a number of enzyme reactions. It is a common deficiency in Australia. Fertiliser is zinc sulfate.

Manganese
Manganese is necessary, but the required quantity varies greatly between species. Evergreens generally use more of this element than deciduous plants do. Its functions are similar to those of zinc. Fertiliser is manganese sulfate.

Copper
Very small quantities of copper are needed, although it is essential. Little is known of its function, but excess copper is known to be toxic and, in some plants, causes an iron deficiency. Fertiliser is copper sulfate.

Molybdenum
This element is essential in nitrate reduction, and is a component of some enzymes that are important in nitrogen fixation, which occurs in the roots of legumes. Deficiency occurs more often on acid soils, though it does occur on some alkaline soils such as in the dry mallee region of Australia. Fertiliser: Ammonium molybdate.

Boron
Boron may assist utilisation of calcium, and may play a part in formation of cell walls. It is involved in cell division and essential to carbohydrate and nitrogen metabolism. Fertilisers are borax or boric acid.

Chlorine
This element is required more than any other minor nutrient, although its functions are uncertain. There are no records of a plant needing to be fed chlorine, although toxicities are known, especially in tobacco and potatoes.

Cobalt
There is no direct proof that this is absolutely necessary in plants, though it does seem important to nitrogen fixation in legumes. It is important to human nutrition in the formation of certain compounds such as vitamin B12. The amount of cobalt in plants can vary greatly.

Silicon
This occurs in greater quantities in monocotyledons (e.g. grasses, iris, lilies and orchids). Silicon does improve the growth of some plants. Some say it is necessary in minute amounts, but this is by no means an established fact.

Aluminium
Aluminium is essential in some species only (peas, corn, sunflower and some grasses). Over 10 ppm is toxic.

Selenium
This element is used in varying amounts by some species only.

Sodium
Though not usually considered essential, sodium can replace potassium as a nutrient, to a limited extent.

Total salts

Most nutrients in the soil exist in the form of a salt (common table salt is sodium chloride, or a sodium salt). Often, when a plant uses a nutrient it doesn't use all of the 'fertiliser'. The unused parts are often salts, and these can build up over a period of time. If too much of this residue occurs it can become a problem. The term 'total salts' refers to the combined effect of all different types of salts in the soil. Individually, salts might not have any effect; combined, they may be toxic to a plant.

Excessive salt is often indicated by a whitish caking on the surface of the soil. Another sign is drying of leaf margin, beginning at the tip of the leaf, followed by death of the tip, then by marginal leafburn. In severe cases, leaves shrivel and whole branches suddenly wilt. Chemical laboratory analysis is needed to confirm the problem. The only solution is to wash the salts out of the soil. In places with inadequate drainage, this is next to impossible. The soil may be permanently damaged unless some form of drainage system can be installed.

Nutrition management

Plants in pots have very limited amount of nutrients available to them, whereas plants growing in the ground can send roots further out to search for nutrients. However, nursery managers usually want in-ground roots to spread as little as possible; to achieve this, they need an adequate supply of nutrients as close to the trunk as possible.

To promote healthy growth, it is important to use the type of fertiliser that suits the needs of the plants you are propagating. Incorrect or inadequate fertiliser will result in plants that are sickly and prone to disease. Factors that need to be considered when choosing a fertiliser include:

- the type of potting mix you are using;
- the type of plant you are producing (e.g. some native plants won't tolerate phosphorus);
- the length of time the plant will be in the pot;
- prevailing temperatures.

When plants are in a potting media for extended periods of time, the pH of the medium tends to acidify (go down), due to several factors. To lessen this tendency, you might use fertilisers that are less acid-forming or a potting mix with a higher buffering capacity. Calcium in the irrigation water at a rate of up to 100 mg/L will also prevent lowering of the pH.

Buffering capacity

Media with the ability to withstand rapid pH fluctuations have a higher 'buffering capacity'. Potting media with a higher buffering capacity will resist pH change and need a greater amount of acid or alkali to alter the pH than do media with a low buffering capacity. It makes sense to select a medium with the highest possible buffering capacity to ensure nutrient availability through the minimisation of unexpected fluctuations in pH. This is most useful for plants grown in containers for long periods. Media with high buffering capacities usually have larger amounts of organic matter such as peat moss, bark and coir fibre. Media with low buffering capacity include sandy mixes containing little organic matter.

Cation exchange capacity

Cation exchange capacity (CEC) quantifies the ability of media to provide a nutrient reserve for plant uptake. Cations are atoms which have lost electrons (with a positive charge). Many important plant nutrients, such as potassium, calcium and magnesium, occur in a soil, media or nutrient solution as cations. These particles are attracted to negatively-charged particles, hence stay in the soil or other medium and are available to the plant roots for longer.

Organic matter such as peat moss and fine particles such as clay have more negative charges on their surface, hence a greater ability to hold cations than larger sand or gravel particles. The more decomposed and (usually) finer the material is, the higher its CEC. Composted materials will therefore have a higher CEC than non-composted bark, which is low. Some minerals such as zeolite have very high CEC, whereas clay minerals are variable.

When a nutrient is applied to a soil or growing medium with a low CEC but a high water-holding capacity the medium will remain moist, but many nutrients will be lost with drainage of excess irrigation water; the medium will become leached more rapidly. A higher CEC reduces this tendency. Mixes with a low CEC require more frequent applications of fertiliser than those with a high CEC. The high CEC medium wastes less fertiliser through leaching, and nutrition will be more even.

High CEC media:

- have greater nutrient-holding capacity;
- retain nutrients for uptake between fertiliser applications;
- retain nutrients during irrigation (prevents leaching);
- provide a buffer from fluctuations in media salinity and pH.

Types of fertilisers

Uncoated pellets and tablets

These are fertilisers compressed or stuck together in a small pellet or tablet. Because it takes time for the tablet to break down, the release of nutrients is slowed and the plant is supplied with food over an extended period of time.

Coated pellets

Coated pellets such as Osmocote, Nutricote and Macrocote are similar to uncoated pellets but have a covering of wax or some other material, which slows the dispersion of nutrients into the soil. Different types of coatings react differently under varying weather and soil conditions, so the product used should be selected carefully according to where and when it is to be used.

Organic fertilisers

These are complex chemicals derived from organic sources, such as seaweeds, fishmeal and bone meal, which often need to undergo chemical changes in the soil before they release nutrients to a plant. These changes are gradual and spread over a period of time, so the supply of nutrients is spread over a period.

Inorganic powders and granules
These are simple chemicals which usually need only a little water before the plant can absorb them. They are generally fast-acting, but any excess tends to leach away and be lost quickly, so they need to be added in small amounts at frequent intervals during periods of rapid growth. Because they act so fast, they are also more likely to burn roots or foliage if applied heavily.

Liquid fertilisers
These are very fast-acting, are already dissolved in water and can be absorbed as soon as they make contact with the plant.

Applying fertilisers

Nursery managers should consider the following factors when planning to apply fertilisers:

- different plants use fertilisers at different rates. Slow-growing plants should be fed at lower rates than quicker-growing plants;
- fertiliser washes through more sandy (better-draining) soils much faster than through clayish soils, and should be applied more often and in smaller quantities on such soils;
- the pH (acidity or alkalinity) of the soil affects the availability of different nutrients in different soils or mixes. If the pH is very acid (e.g. pH 4), certain nutrients such as iron are more readily available to plants, but others (e.g. nitrogen) cannot be taken up as easily as they are at a higher pH. Every nutrient has its ideal pH. Different plants require different amounts of different nutrients, and this fact makes it preferable to have the soil pH at different levels to achieve the optimum nutrient uptake with different types of plants. Some things grow better at pH 5, others are better at pH 7; most prefer pH 5.5–6.

Methods of application

1. Mix straight (organic or inorganic) fertilisers into potting soil before plants are potted, and follow with applications of liquid fertilisers at regular intervals. Soil/media with such fertiliser incorporated must be used quickly (within a week or two of adding fertiliser). The fertiliser can leach out or change form if left for any period.
2. Mix fertilisers into the soil before potting, then add additional fertiliser by topdressing on top of pots or on the ground at the plant base. Frequency of topdressing depends upon the type of fertiliser being used and on the ability of the potting mix or soil to leach out or retain applied nutrients.
3. Mix slow-release fertilisers such as Osmocote into the soil from the beginning, before plants are potted or planted in open ground. The slow-release fertiliser

might or might not be sufficient to feed the plant for its entire life in the nursery. Temperature and moisture can affect the speed at which the fertiliser is depleted. Some fertilisers do not work at all in cooler climates during the winter months, and should normally be used only in subtropical or tropical regions. Any fertiliser mixed into a soil must be mixed thoroughly and evenly. Some nurseries do this themselves using a cement mixer, adding the fertiliser as they use it; others have the soil supplier mix fertiliser for them.

4 Apply slow-release fertiliser to the plant base after planting or potting. Some nursery managers prefer this method because it allows them to apply different types of fertilisers to different plants, and because it does not have the problem of having to ensure a thorough mixing of fertiliser in the soil/potting mix. It is important that the person doing this job does not overfeed or underfeed. (A 'pinch' is not precise enough). Variations in the rate of feeding can cause variations in the growth habit and rate of plants. A set measure per plant is required.
5 Use liquid fertilisers only, normally applied through sprays or the normal watering system (sometimes called fertigation). Liquid feeding can vary from daily to once every 5–6 weeks. There are disadvantages to both methods. The danger is that overfeeding can burn plants and underfeeding will not achieve the growth required. The rate of feeding must be calculated carefully, and the application of liquid feeds should be very precise.

The simplest device for application of liquid fertiliser is a standard chemical sprayer. Because of the quantity of plants being fed, the chemical is normally applied in a concentrated solution and immediately watered with normal irrigation to wash it off the leaves and into the pots (preventing burning of the leaves).

A better method involves automatically mixing the fertiliser into the irrigation system using a fertiliser injection device such as a Geewa. These units are precise, and allow the fertiliser to be applied at very low concentrations regularly, quickly and with very low labour costs. This type of unit could cost anything from $A400 upwards.

Fertilising at the propagation stage

Nursery managers have differing attitudes towards using nutrients or fertilisers during the propagation stage. Some believe it enhances propagation; others see no overall benefit. Research has shown some benefit with some plants, but there is no real consensus on the benefits of widespread fertilising during propagation.

Fertilisers are not generally readily absorbed by cuttings until roots begin to develop, and there is very little evidence to suggest that adding nutrients helps root initiation. However, there is evidence that adding nutrients after root initiation, in some species, will help speed root development. Medium to high concentration of fertilisers may damage newly developing roots. Fertiliser applications may also encourage the development of other organisms, or encourage the foliage of cuttings to grow at the expense of root development. Some slow-rooting cuttings, however, may benefit from weak foliar applications.

Nutrients added to the mist system during propagation have been shown to promote root and shoot growth in some woody plants. Generally, nutrients are applied as soon as possible after roots appear on a cutting or seedling. The level of nutrient application for optimum growth varies between plant varieties. The level is the same for older plants as it is for young seedlings or rooted cuttings.

The balance between carbon and nitrogen has a significant effect on root formation. A high carbon or carbohydrate level and low to moderate nitrogen level favours rooting of dormant (leafless) cuttings. With no leaves, hardwood deciduous cuttings must rely on stored carbohydrate, because they cannot photosynthesise and produce new carbohydrate. High nitrogen tends to reduce rooting. By reducing feeding of nitrogen to stock plants for a period before taking cuttings, the levels of nitrogen in the cutting material can be reduced, which in turn can stimulate rooting when the cutting is taken.

Fertilising problems

Moss/algae/liverworts

These can often grow on the surface of pots. They can indicate dampness, but can also result from levels of nutrients on the surface of the pots. If a layer of coarse sand is sprinkled on the top of the pot, restricting light to the fertilised soil, this will deter the growth of such substances.

Salt build-up

A white cake on top of the soil indicates a build-up of salts from applied fertilisers. This can damage plant growth, and generally indicates overfeeding or insufficient leaching of waste salts.

Runoff

Runoff (excess water flowing through the soil or pots) from a nursery usually contains high levels of salts and unused fertiliser, which can lead to soil and other pollution problems as they drain away from the nursery into neighbouring properties. Legislation has been introduced, or is being introduced in parts of Australia, the US and other countries to force nurseries to collect and treat their polluted wastewater.

Some runoff problems result from a tendency to overfertilise, especially with liquid fertiliser. This could cause significant overspending in unwary nursery managers, who should take care to apply the correct amount for the plant. Most nurseries use slow-release fertiliser for their container-grown plants. Nutrient release for these fertilisers is mainly through temperature and moisture; through the plants' growth cycle, excess nutrients, particularly nitrogen, may be released.

Best-practice guidelines for the nursery industry in relation to management of potting media and fertiliser can also help prevent these problems. Nurseries should:

- use controlled-release fertiliser instead of soluble fertiliser;
- always determine the correct amount of fertiliser required to sustain good plant health and growth;
- apply at recommended rates;
- apply at intervals, not large quantities in one application;
- take into consideration their irrigation practices, rainfall and geographical area;
- take into consideration the capability of soil infiltration in relation to water-soluble fertilisers;

- use wetting agents and media to assist water retention;
- review their watering methods and develop new methods where appropriate;
- correctly store media and fertiliser to prevent contamination through spills and runoff;
- understand the correct procedures for cleaning up spills;
- monitor drainage discharge and install specific holding ponds, tanks or filtration systems as needed;
- be especially careful in hot and wet conditions. These conditions can cause some fertilisers to release their nutrients too fast, burning the roots of plants and/or wasting fertiliser. Instead of encouraging growth, the fertiliser might damage the plant.

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Nursery materials and equipment

The nursery industry is constantly changing its production practices as new production systems, research, machinery and nursery materials are developed. The appropriate choice of materials and equipment can have a major impact on the productivity and profitability of a nursery. In advanced tree nurseries, for example, there is a move towards growing trees in large sturdy plastic bags to an advanced stage. The bags are individually irrigated through a trickle irrigation system. This growing system eliminates the need to use large machinery in the digging-out process, reduces shock and damage to the plant, and reduces the labour costs associated with field-grown plants.

Another very recent development is the pot-in-pot method. This production system is an alternative to growing trees and shrubs in-ground or in above-ground containers. Instead, a planted container is placed in a holder pot that has been permanently placed in the ground. Each pot is drip-irrigated, preventing losses during dry spells.

The advantage of this system is that it eliminates heat stress and the death of roots through the high temperatures created in conventional containers; it also insulates roots in cold weather. Loss of plants, media and fertiliser through plants falling over during windy conditions is also eliminated, thereby reducing labour and production costs.

Plants sell better when packaged or presented in sturdy and attractive containers with appealing labels. Depending upon the task at hand, materials should be chosen for ease, speed of production and optimum plant growth (e.g. square pots are easier to fit into trays and prevent circling root systems).

Medium to large production facilities justify the installation of less labour-intensive production systems such as potting machines, automated or remote control temperature and watering systems.

Containers

There is an enormous range of containers suited to nursery use. The choice of container is generally influenced by the cost and the application; for example, nurseries producing tubestock use small containers ranging from 2 cm (1") to 10 cm (4") diameter. Propagation nurseries may use trays rather than pots to strike cuttings. Although price is an important factor the cheapest container is not necessarily the one which will grow the best plant, or help the plant sell best. Consider the following examples.

- Nurseries that automate seeding or potting must use pots which are compatible with their machinery.
- Some containers (e.g. bags) may be cheaper to purchase but more difficult to handle, so what is saved on the cost of the pot may be lost on labour.
- Production nurseries that recycle pots must use containers sturdy enough to be reused and have the facilities to sterilise them.
- Higher-priced 'special plants' such as bonsai, Christmas trees or topiary usually sell better if they are in a more attractive and expensive container.

Requirements of a plant container

- The container should have adequate drainage holes but the holes should not be large enough that potting media falls out.
- The container should make efficient use of space (good ratio of soil volume to the amount of ground space used).
- The pots should be easy to separate when placed in a stack.
- The container should be strong and durable.
- The container should produce suitable root growth (root coiling should be minimised).
- The pots should be easy to handle (they shouldn't tip over or be too heavy).
- They should be readily available (the supply must be dependable).
- The amount of drainage in a pot determines the ratio of air to water in the root zone.
- A pot should have drainage characteristics which allow the soil to remain moist, but not wet.
- If all other factors are equal, a deeper pot tends to drain better than a shallower one. Overwatering is more likely to be a problem in squat pots or trays than in deep tubes.
- In some plastic pots the drainage holes are not cut cleanly. Pieces of plastic hanging over the drain holes can partially or fully block them.
- Glazed ceramic pots with only one hole in the bottom may have drainage problems.

Critical factors for a container

- Is the container manufactured from a durable material? Metal can corrode, wood can rot.

- Is the container porous? Does the water soak through the sides, as occurs in unglazed clay pots, or is it sealed like plastic pots?
- Consider the number and size of drainage holes at the bottom. Potting mix can wash out of large holes, but small holes do not allow adequate drainage.

Comparing container materials

Plastic containers

- Do not dry out as fast as terracotta.
- Lightweight.
- Virtually unbreakable – they should be discarded if cracked.
- Range of colours available (can be a useful marketing tool).
- Relatively cheap.
- New plastics are UV stabilised – this increases their life-span.
- Easy to store and clean.
- Available in a range of textured finishes and styles (e.g. 'terracotta').
- The basic pots used by wholesale nurseries.

Fibreglass containers

- Clean and durable.
- May eventually discolour.
- Medium life-span.

Terracotta containers

- Unglazed pots absorb moisture and release water from the sides of the pot, possibly resulting in plant stress.
- Glazed pots may suffer from waterlogging if there are insufficient drainage holes.
- Plants need to be watered more frequently.
- When broken, they can be repaired but may not look good.
- Salting on sides may occur if mixture is kept moist.
- More expensive than other containers.
- Very durable, tough and long-lasting, but heavy.

Timber containers

- Can rot after a year if not treated.
- Natural appearance appeals to many gardeners.

Concrete containers

- Available in almost any size.
- Very heavy and expensive.
- May affect pH due to lime leaching out of concrete.

Brass containers

- Very expensive, therefore usually only used indoors.
- May need polishing if not treated.

Paper containers

- Recycled paper pots are available in different sizes. They have a definite appeal to a growing niche market, but reliability of supply has been a problem at times.

Containers for propagation

The type of containers chosen for seedling propagation is as important as the nursery management system used, and can affect plant quality. Certain seedling containers, for instance, are now designed to maximise the gains made by a seedling once it is planted into open ground.

This is particularly the case for plants that are grown in large quantities for revegetation purposes or as farm trees. The choice of container is an important decision, as once a production system is in place it is usually geared towards the type of containers used. Changing containers can therefore be an expensive process that may require new potting machines and benches etc. as well as a complete change in the production process – watering systems, fertiliser programs and media usage.

Containers should also be chosen to facilitate root pruning and training, particularly for seedling production. The pruning of roots once they reach the bottom of a cell prevents root spiralling in the cell and encourages lateral root development.

Figure 9.1: Jiffy containers are actually compressed peat that swells when water is added. They are used for propagation, but can restrict root growth.

Propagation blocks
These units allow sterile propagation of plants. However, they do not contain any nutrients so the plant must be potted-on once roots become evident. They also tend to constrict root growth. Synthetic block units include foamed polyurethane, mineral wool (e.g. rockwool), phenolic foam and vermiculite blocks.

Compressed peat-based blocks
These come in slabs with block sections, as preformed pot strips that need to be filled with a propagation media or as individual compressed pots surrounded with a fine netting that expands when watered (e.g. jiffy pots). Research indicates that these can tend to restrict root development.

Plastic units
Punnet-size flimsy plastic containers have been developed for individual seeding. These punnets are made with 6, 12 or 24 units. Tray-size containers with 24, 40, 60 or more units are also available. These are filled with the appropriate propagation media and the seedlings are grown until they are large enough to pot-on.

Plastic seedling trays
Seed is sown directly into the trays to achieve maximum space efficiency, most commonly used in mass production systems. The trays contain individual cells for each seedling; the most commonly used tray has 64 cells. However, the process of transplanting, if not handled carefully, can cause severe root damage to small seedlings.

Special plug-popping pads are used to remove seedlings from the cells by popping them up by about 30 mm (1.25"), from underneath the tray. Both manual and mechanical plug-poppers are available. They reduce root damage as well as transplant stress. The mechanical foot-operated plug-poppers are most usually used in the nursery. Manual poppers are more commonly used in the field for quick and easy removal before planting.

Plastic pots
Pots are use for propagating larger-sized materials, such as cuttings and large seeds. They minimise root disturbance when the plant is finally potted-up.

Labels

In recent years labels have become more than just a way for customers and nurseries to identify the plants sold. They are increasingly becoming a major marketing tool, with some companies producing corporate-type labels to not only promote stock developed through their business, but also to promote their nursery. Corporate-type labels are recognised by consumers as representing one business and also (usually) a quality plant. They are showy, colourful, sturdy and eye-catching.

There are several types of labels used in the nursery industry:

- tie-on labels – available in a range of sizes and quality, from standard through to premium quality;

- push-in labels – available in a range of sizes and quality from tiny tag labels to large showy colourful types, and specifically designed ones for bedding plants;
- customised labels – specifically designed, may even use holograms and foils and are very high quality, to promote specific businesses as well as specific plants;
- descriptive labels – used when a picture is not needed or as an extra to a promotional label; usually a push-in type outlining cultural requirements.

Some label-makers also supply promotional material in the form of posters and cardboard displays.

Plant labels fall into the categories described in Table 9.1.

Table 9.1: Categories of plant labels

Category	Good points	Bad points
Solid plastic (stick-in)	Strong, durable, inexpensive, reusable	Not attractive, sometimes lost under foliage, can be removed
Cardboard (tie-on)	Cheap, easier to see	Can ringbark plant if left on too long, will decompose/be eaten by snails etc.
Flexible plastic (stick-in)	Medium cost, medium durability, water-resistant	Become brittle, not reusable
Flexible plastic (tie-on)	Medium cost, medium durability, can be placed in a prominent position on plant	Become brittle when exposed to sun, can eventually ringbark the plant

Printed or non-printed labels

Another factor to be considered with labels is whether to use printed labels.

Blank labels

Blank labels allow nursery managers the flexibility to write whatever is appropriate on a label. More work is involved because you must handwrite every label using a water resistant pen or pencil, and it is difficult to write as much information in the space that a printed label would occupy. This type of label is most often used in propagation trays and for groups of tubestock etc. where the label is seen only by nursery staff; it is replaced with a professional one at the point of sale.

Printed: writing only

Printed labels save the time and effort required for writing labels and allow more information to be included on the label (plant description as well as name, and perhaps nursery name). They can be expensive if growing a large variety of plants but they have a professional appearance.

Printed: picture labels

These contain a photograph or other image of the plant on one side and a description on the reverse. They are a very good sales tool, especially for selling plants when they are not at their most attractive (e.g. deciduous plants in winter). However, they are very expensive compared to other options.

A label is the key to marketing. If it is well-presented, easily read and informative it will help sell the plant. Labels with diagrams depicting sun requirements, planting method and depth, and ornamental shape are a bonus and will help sell the plant.

Matching labels with plant stock

When selecting labels it is important to target your clientele. Labels for retail sales should be colourful, and should include both botanical and common names, as well as a brief description of the plant (height, growth habit, evergreen or deciduous, soil requirements, flower colour and season etc.). Labels for wholesale production often need only the botanical name, but should be durable and weatherproof.

The type of plant grown can also influence the choice of label. For example:

- bare-rooted deciduous fruit trees – customers must rely totally on the label so it is best to use a pictorial label with planting instructions and fruit characteristics. The scion variety material should also be stated;
- herbs – many gardeners are not sure what to do with herbs so it is advisable to list uses as well as cultural details;
- potted or bare-rooted roses – durable coloured pictorial labels with care instructions should be used;
- bedding plants – coloured pictorial labels are helpful, especially for newly introduced varieties;
- potted conifers – coloured pictorial labels are best as they show how the plant will look in the future;
- cacti – a descriptive written label is usually sufficient;
- trees and shrubs – details of mature height and width are very important.

Promotional labels should be placed in a prominent position, preferably at eye level or just below to intercept customers' eyes as they scan the nursery. If labels are too high, customers will not see them because most people look down as they stroll through the nursery.

The labels should be weather-resistant and feature large, colourful and simple-to-read information. The label should not be cluttered with written text. If the plant labels are detailed, the promotional label should not contain all the same details.

Stakes, trellises and trainers

Stakes, trellises and trainers are used to:

- provide strength for weak-stemmed plants until the plants are strong enough to stand on their own. Young growth on many plants is prone to breakage by wind gusts or the weight of the foliage when saturated from irrigation water. A stake will support tender plants in the early stages of life;
- guide growth in a particular manner. The reasons for guiding plant shape can be:
  - to modify plant habit – some plants tend to grow in a horizontal pattern in the early years, thereby taking more time to reach marketable size;

- to produce an attractive plant – climbers trained onto a small trellis appear lush and are more likely to be sold than a climber on a single stick;
- to train plants into shapes – topiary is a technique used to train and sell plants to a select market niche;
- to control growth – climbers look messy and unattractive to buyers if the leaders are hanging down from all sides.

You should determine how long the stake or trainer is to be left with the plant. If it is to be left intact for a few months or years, it must be very durable and strong. If it is only a temporary support, then a lightweight product should be used. If it is to be removed once the plant is planted out in the garden, then a cheap alternative might be considered. If the quality of the overall marketed product will be reduced by a particular stake, choose a better-quality stake even if it is more expensive.

Mulches

Mulches are useful in nurseries for controlling weed growth, keeping plant roots moist and cool and as a clean surface to cover the ground.

Control weed growth

Weeds can be a serious problem in a nursery. A single weed can sometimes produce thousands of seeds which can then find their way into plants throughout the entire nursery, resulting in a lot of hard work. The answer is to never let weeds go to seed or, even better, never let weeds grow in a nursery at all. Thick mulching along fence-lines, beside buildings and any other areas may save a lot of headaches later on.

Figure 9.2: This woodchip mulch is being used as a weed suppressant in a nursery display garden. Many nurseries stock the items used in their display gardens.

Keep plant roots cool and moist

Plants grown in the ground (in nursery rows) may benefit from mulch, particularly during warm weather. Plants in pots can also be mulched, though the labour required to mulch small pots might not be cost-effective. Mulching the surface of advanced plants in large tubs certainly is worthwhile. Mulches can extend the growing season of plants and reduce the amount of watering needed.

Cover the ground

Surfacing the ground is important both on paths and roads (to improve access and cleanliness), and in growing-on areas (to minimise the likelihood of pot bases coming in contact with soil diseases and pests). Ideal surfaces to stand pots on are concrete, asphalt or some other hard, well-drained pavement. This is extremely expensive, though, and for most nurseries the cost is too high, at least during their establishment phase. Hard surfaces are often used for propagation areas and perhaps pathways, but some type of mulch is used for the rest of the nursery.

Aggregate or stone mulches are often preferable because they quickly drain water away from the base of the pots and dry out fast. Organic mulches or even plastics or other horticultural fabrics are sometimes used, though, because of cost considerations.

In retail pots

Mulches may be used to improve the appearance of a pot, prevent weeds growing and help to conserve water in the pot. The choice of material used in nurseries includes peanut shells, pinebark, sugarcane mulch and coconut fibre.

Nursery tools and equipment

The equipment used by staff in a nursery can make a great difference to overall productivity. A lack of spending in this area can make it impossible for staff to do an effective job, even if they are very skilled and competent. On the other hand, excessive spending can result in a significant waste of money that could be better spent elsewhere.

Good management of tools and equipment involves:

- choosing the right type and quantity of tools and equipment in the first place;
- making sure tools and equipment are used and maintained properly;
- upgrading or replacing tools and equipment at the right time.

Design of tools

You should choose tools and equipment which are strong enough to withstand constant and sometimes heavy use. Remember that nursery tools are going to be used frequently, maybe every day, whereas tools for the home garden are used only occasionally. Consider the following:

- strong tools will take greater physical stress and handle heavier jobs without breaking. If you buy a cheap tool constructed of low-quality materials it might not last to the end of the first day, particularly if you are doing heavy work;

- sharp tools put less stress on the tool, and less strain on the user;
- long handles give greater leverage and increased reach, putting less strain on the user's body. However, they are sometimes impractical, especially if the tool will be used in confined spaces;
- some tools are more expensive because long hours of thought have gone into their design, not just because they use better materials. Tools which do the job better and more easily may be more expensive, but they are worth it;
- heavy clay or rocky soils are likely to put more strain on tools and equipment such as spades and cultivators – in these conditions you will need better-quality and heavier-duty tools;
- metal tools made of stainless steel or aluminium do not corrode like those made with other metals.

A guide to purchasing tools and equipment

Before you buy a tool or piece of equipment you must decide whether the business really needs it. The need for that equipment should then be balanced against the cost, both initial and ongoing, and the operational requirements. Is it really a worthwhile proposition? This must be decided by such factors as:

- whether it will do the required job;
- initial outlay – how much it costs to buy;
- ongoing costs – this includes maintenance, parts, fuel and insurance;
- reliability – whether it breaks down frequently;
- longevity – how long it will last;
- safety of use;
- availability of parts and servicing.

To rent or buy?

Often a viable alternative to buying is to rent equipment, either long- or short-term. These days you can hire most types of commonly used horticultural equipment, such as rotary hoes, tractors and chainsaws. Factors to consider include:

- how often you use the equipment – why buy when you can hire the equipment on the occasions you need it;
- upfront capital costs – can you afford to buy the equipment or would it be easier to pay periodical rental or leasing costs;
- whether you have the technical expertise to keep the equipment in good working order – good rental companies keep their equipment well-maintained and serviced and will replace faulty equipment;
- in some cases the lease or rental hire may be tax-deductible.

Manual potting equipment

Smaller nurseries may find that their level of production would not justify the purchase of specialised potting equipment. The minimum potting equipment required includes:

- nursery trolleys for moving plants;
- solid washable workbenches (galvanised metal top) suited to propagation and potting activities with storage underneath for pots and trays and shelves above for labels, markers and propagating equipment;
- an adjacent undercover media storage area with a concrete base. This should be located so it is accessible from both sides for media delivery and to allow the media to be shovelled onto potting benches;
- a mobile bench/potting cart is also a cheap and worthwhile investment. This allows the potting media to be moved to where it is needed, and doubles as a potting bench. The cart can also be used to move potted tubes to the growing-on area;
- a rotating table (lazy susan type) suited to potting-up plants.

Figure 9.3: This nursery trolley is being used as an inexpensive mobile potting bench.

Nurseries with medium production runs may consider using:

- a potting station or potting hopper and bench. The potting station usually incorporates a gravity-feed hopper that can be bulk- or conveyor-filled, that is easily adjustable to suit various pot sizes. This type of station has no movable parts, making it easy to maintain and reliable to use. The hopper and bench type is usually made from heavy galvanised steel. The hopper is bulk-filled and tubes, trays and pots of all sizes can be straight filled;
- storage hoppers;
- trailers specifically built to suit narrow and confined spaces;
- a small tractor is particularly useful in medium to larger operations where a lot of material, equipment and stock are constantly being moved;

- nursery trolleys are an essential item in every nursery. These are two-, three- or four-wheeled trolleys with a wide shallow tray primarily used for moving plants around the nursery. Most trolleys hold both pots and seedling trays. The trolley tray is covered with a metal mesh that allows water to freely drain away when plants in the trolley are watered before unloading. Several trolleys should be conveniently located in production areas for nursery workers and in sales areas for customers to transport their selected plants;
- hand trolleys, which are useful for moving many things about the nursery including boxes of materials (chemicals, pots, stationery, tools etc.) when delivered and large planter tubs when a forklift or tractor isn't available. They are particularly useful in retail nurseries or at shows and exhibitions where a small upright trolley is more manoeuvrable than a larger nursery trolley in a confined space.

Figure 9.4: Nursery trolleys are a standard piece of equipment that may be used by staff and customers alike.

Additional potting equipment suitable for larger nurseries

Soil-mixing equipment

Cement mixers (small or large) are sometimes used for mixing potting media in nurseries that make their own mixes. In some bigger nurseries large amounts of soils, composts, mulches or growing media may be mixed or transported using a front-end loader. Ideally these materials should only be mixed and stored on a clean surface such as concrete, so they are not contaminated by soil particles and soil-borne pests and diseases from underlying soil.

Conveyor belts

Conveyor belts can be used to move plants away from work areas to growing-on areas as well as moving media from hoppers to potting machines or benches. They are not viable in small nurseries, but some large nurseries have found that they can contribute towards improved productivity.

Potting machines

Potting plants is extremely labour-intensive and many nurseries have found that automated potting machines significantly improve nursery efficiency. There are a number of different models available, including machines which do the following:

- controllable volume system – the amount of soil poured into the pot is controlled by pushing a foot pedal/hand button. Soil will be delivered until the pedal/button is released;
- pre-set volume – the volume of soil is pre-set, although it can be changed for different sized pots and plants etc.;
- combination of the above – more-sophisticated machines can be set to either method. Pots can be moved along a conveyor belt or set on rotating benches. The soil may be fed through a central hopper or along a conveyor belt.

Potting machine rates

Statistics given vary from 200 per work hour to 500 per work hour, potting into rigid 7.8 cm (3") pots, and including all operations (bringing in soil mix, cuttings, potting, placing down and watering in, but excluding taking away to nursery rows).

Table 9.2: Total labour for potting expressed in minutes per plant (potting into rigid pots)

Container size – plant type	Average (minutes)	Best (minutes)
2 L (0.44 gallon) – general shrubs	0.93	0.74
3 L (0.66 gallon) – general shrubs	0.98	0.78
2–3 L – climbers	1.06	0.89
2 L – clematis	1.16	0.93

These figures do not include bringing soil to the potting bench, or taking away potted plants (J. Edmonds, *Container Plant Manual*, Grower Books).

Seeding machines

There are different types of seeding machines used by nurseries. Most feed seeds into soil or potting media by a vacuum mechanism (seeds are picked up when a vacuum is created, then dropped into the desired position when the vacuum is disengaged).

Using these machines, plants grown in the field may be direct-sown into nursery rows. Plants grown in containers can be grown by using a seeding machine and a compatible transplanting machine. Many annual and vegetable seedlings are propagated into 'plugs' using this type of equipment. Seedling nurseries have effectively halved their labour costs by using this type of machinery – despite the high cost of the machine, the cost benefit can be enormous.

Tray filler

This is used to fill seedling trays. It has an adjustable vibrating system and a height-adjustable rotor that ensures uniform soil density as well as equal soil distribution. The filled trays are finished and cleaned with a height-adjustable, fast-rotating brush unit. This equipment also has easily adjustable speed and height settings, improving the productivity rate; for example, machines can fill 700–2000 average-size trays (520 mm × 40 mm, 20" × 1.5") per hour depending on the speed setting. This equipment usually comes with options such as automatic tray dispenser, watering system, conveyor and seeding/dibble equipment.

Sprayers

Sprayers are used for applying chemical sprays (insecticides, fungicides and herbicides) or liquid fertilisers. It is advisable to use a different sprayer for each type of chemical. Herbicide residues from previous spray jobs can contaminate insecticides and damage plants being sprayed for insects.

There are many different types of sprayers available:

- disposable spray guns – plastic bottles with a pump-action handle on top. Many chemicals are sold as a ready-to-use spray in this type of bottle. Refill bottles can be screwed on to the spray mechanism top;
- pressurised back or shoulderpack units – a container which can be pressurised with a flexible hose and connecting spray nozzle. You pump by hand to raise the pressure in the container then use the trigger to release pressure and spray as required;
- motorised sprayers – the chemical is pumped from its container by a motorised pump, out through a spray nozzle.

Table 9.3: Comparing sprayers

	Disposable sprayguns	Pressurised backpacks	Motorised sprayers
Cost ($A)	Under $5	$50–200	Most
Durability	Use only a few times	Fair to good	Generally good
Parts availability	Not worth repairing	Parts available	Parts can be repaired
Likely problems	Pump action	Washers leaking	Nozzle blockage
	Seal damage	Nozzle blockage	Engine problems

Sterilising equipment

Larger nurseries mixing their own media must use sterilising equipment to eliminate harmful bacteria but leave beneficial organisms for healthy soil. Fan-forced steam sterilisers with selected temperature and soak times are used for this purpose. The sterilisers are usually trailer-mounted – the top of the unit is removed and the trailer is towed to the potting bench, avoiding double-handling.

Heating trays (commercial propagation)

There are various commercial propagation trays available including fibreglass, heating cable on wire mesh and flexible heat mats.

Some trays are available with both heating and misting for independent use, or heating-only for use in humidity-controlled environments such as hothouses. There are different sizes available, or trays can be custom built to suit commercial growing needs. Misting equipment and sensors are also available for hothouse use.

Capillary matting
This reduces water usage as less overhead watering is required; the water is absorbed into the pot through a wick action from the mat set in a galvanised metal tray underneath the pots. The mat has a water-holding capacity of around 600% its own weight, or around 2 L/sq m. It also controls weeds, reduces fungal disease, ensures even moisture distribution and is very easy to install.

Miscellaneous ancillary equipment
Humidity meters, soil thermometers, moisture meters, maximum–minimum thermometers, digital thermometers and other equipment may be of use in larger nursery operations.

Using tools

Tool tips

- Don't overload tools – you will only damage a tool or piece of equipment and perhaps lose control, slip or fall and damage nursery stock, equipment or yourself.
- Have a clear working area – obstacles and uneven working surfaces put a strain on both the worker and equipment, particularly when moving heavy or awkward things.
- Get help to do things which are difficult with only one set of hands. Part of good nursery management is knowing how many people will be required for a certain task.

Manual handling techniques

Some simple techniques can prevent a lot of the common injuries from manual handling of objects. This applies to many tools that are generally used in nurseries. These techniques include:

- always bending your knees and keeping your back straight when reaching down to pick up something;
- not attempting to lift anything that may be too heavy for you. Try rocking the object first to get an idea of its weight. Get help if there is any doubt about whether you can easily lift the object;
- using work gloves and safety boots, particularly if the object may have sharp or rough parts, where insects or spiders may be present, and in case you drop the object;
- not overexerting yourself or putting yourself in a position where you can overbalance. This applies particularly when straining to use tools such as rakes, shovels, crowbars and heavy mechanical equipment.

Maintenance of tools and equipment

The first step in tool maintenance is to read any instructions or manuals supplied with tools and equipment. Regular servicing or maintenance procedure may be required. If there are no specific instructions, a number of simple maintenance tasks generally help prolong the life of many tools.

Looking after tools is very important. If you look after them they don't have to be replaced as frequently. Tools in good condition are easier and safer to use. Some simple general reminders are listed below:

- metal – to prevent rust or corrosion, metal needs either painting with a good metal primer or regular coating with oil (after use, clean and wipe metal parts with an oily rag);
- sharpening – keeping your tools sharp usually means less effort is required to use them, so less strain is applied;
- washing – if tools are kept clean they are less likely to corrode or have moving parts seize. This also reduces the likelihood of pests and diseases being spread from infected areas to uninfected areas;
- storing – keeping your tools stored properly means they are less likely to be damaged, lost or stolen. Tools left lying around can also be dangerous, particularly if your business is likely to have young children visiting (a retail nursery) or if they can be used by burglars to break into your office, work buildings or storage sheds;
- make sure all parts of the tool are free of foreign matter or obstructions that may impede the efficient and safe use of that tool;
- make sure that worn or damaged parts are replaced promptly. This includes pull-start cords that might be frayed;
- make sure that all moving parts are well-lubricated;
- protect (paint or wipe with an oily rag) any parts that are likely to rust or become corroded;
- keep battery terminals free of corrosion (cover terminals with a smear of petroleum jelly) and battery levels topped up. All connections should be kept tight;
- make sure any oils are kept topped up, and drained and replaced at regular intervals. Oil filters on machinery should be replaced at regular intervals (follow manufacturer's recommendations);
- keep air cleaners clean and unblocked;
- keep any cutting edges properly sharpened;
- periodically check for and tighten any loose nuts, bolts, screws etc.

Hand tools

Secateurs

Every nursery, whether it a production, growing-on or retail nursery, needs a pair of secateurs. There are two main types of secateurs:

- scissor cut – where the cutting action is achieved by two blades shearing past each other. The scissor cut is clean and doesn't bruise the plant, provided the tool is kept in condition;

- anvil cut – where a sharp blade comes straight down on a flat (anvil) surface. This type generally cuts more easily than the scissor type but can bruise or tear if the blade is not kept very sharp.

How to cut using secateurs
All cuts should be made at a sharp angle in relation to the ground. This prevents water from collecting on the cut surface, thus reducing the likelihood of disease problems. Where possible, cuts should be made just above a node (where the leaves and/or flower stems are, or have been, attached to the plant stem). This reduces the likelihood of dieback along the stem. It is also important to only cut material that is not too thick for the secateurs (ideally no more than 1–1.5 cm (0.5") depending on the secateurs), otherwise the cutting will strain both the secateurs and yourself, and the final cut is likely to be rough, torn or uneven. When using anvil secateurs you should always cut down onto the anvil.

It is important to sharpen the cutting blades regularly with a sharpening stone. On anvil type secateurs, the blade should be sharpened on both sides. On scissor cut types, the blade should only be sharpened on one side (the outer edge, the side which is furthest from the other blade when a cut is made).

Knives

Knives can be used for a variety of jobs in a nursery including budding and grafting, preparing cuttings, layering, dividing plants and pruning. Because it is a small and convenient tool many nursery workers carry a knife at all times just in case they need it for these or any other jobs. It is best to use the appropriate knife for the job at hand, and there are many different types of knives. Knives can have either fixed blades, folding blades or disposable blades:

- folding-blade knives – this is the most common type of knife used in nurseries. A normal pocket knife or even a Swiss army type knife might look like a propagation knife, but they are not designed for this purpose. Different folding-blade knives are designed for different tasks,

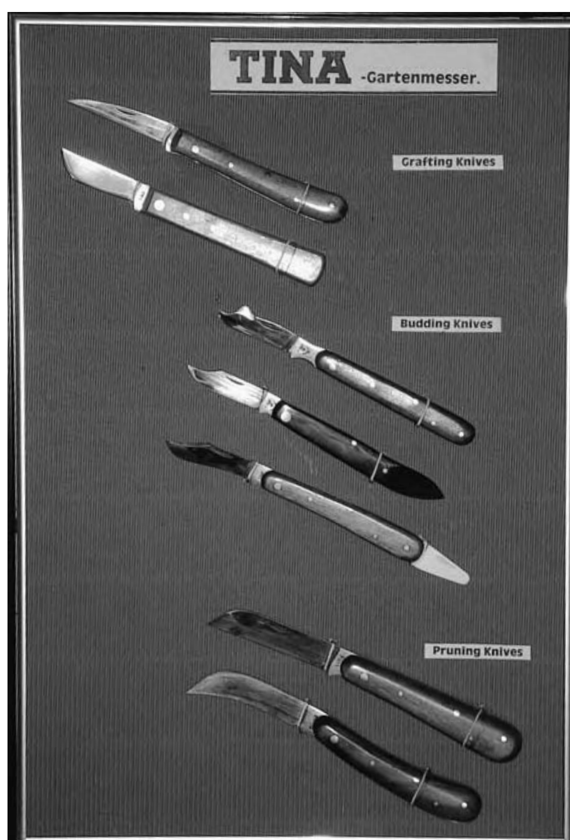

Figure 9.5: Knives in the nursery can be used for dividing clumps of perennials, budding, grafting and pruning.

so either use several different types of knives or choose a knife designed for your most common task;
- fixed-blade knives – the main advantage is that the blade can't move when it is being used, so there is less chance of an accident damaging either human flesh or plant tissue.

Knife characteristics

- Type of metal – stainless steel knives are often cheaper, but do not keep their edge as well as more expensive knives made with high-quality steel. Expert propagators need tools to suit their skills if they are to perform to the best of their ability, but unskilled labour will probably misuse and not get significant value out of more expensive knives.
- Single- or double-angled blade – single-angled blades are ground on one side only, so one side of the blade is sloped and the other is flat. These can only be used to cut with the flat side against what is being cut. Most specialist knives are single-angled. Double-angled blades are sloped on both sides and cuts can be made any way. Knives for T budding are made this way.
- Weight – knives are more efficient if most of the weight is in the handle. You can test where most of the weight is by balancing the knife on your finger.
- Handle – the handle should be comfortable in your hand, particularly if it is to be used for hours on end. The point of attachment between the blade and the handle is a weak point and on less expensive knives the blade may become loose.

Knife applications

- For dividing large clumps of perennial plants, a large sturdy knife may be most appropriate. It will usually meets rough treatment coming in contact with soil, and needs to be sharpened regularly.
- For budding, a lightweight folding knife with a spatula on the end (for handling buds and lifting bark) is the traditional tool. Some nurseries find these expensive knives frequently go missing, so use cheaper alternatives such as razor blades in a protractible plastic holder.
- Grafting knives come with curved or straight blades, though straight-edged blades are preferred.
- Pruning knives are traditionally larger knives with curved blades used for deheading (cutting the tops off perennials at the end of the season), or taking the tops off rootstocks before grafting.

Hand saws

Hand saws have a variety of uses in the nursery ranging from pruning and lopping to constructing fences and garden furniture. The most commonly used saws in the nursery are listed below.

- Pruning saws – these generally have teeth designed to cut moist living timber; the teeth are usually larger than those on saws used for cutting furniture or construction timber. There are two types of pruning saw:
  - straight-bladed, which allows variation in the type of cut according to the type and size of the material being cut;
  - curved blade with teeth on one side. This curved saw is generally used by experts because the curved blade allows access to restricted areas such as near closely interlocking branches.
- Bow saws – as the name implies, these saws are bow-shaped. They are lightweight, easy to use, have replaceable blades and coarse teeth which provide a fast cut when the blades are in good condition. This type of saw is popular for pruning branches that are too thick for the light pruning saws.
- Carpenters' saws – there is great variation in the types of saws used in carpentry work. Generally they have finer teeth than pruning and bow saws, set to give a narrower cut. This is because they are mainly used for cutting processed timber (dried, milled, heatpressed and treated etc.) where a narrower, finer cut is required. These saws are predominantly straight-edged with teeth on only one edge of the saw.

Simple rules when using hand saws

- Always keep the saw sharp. This makes cutting easier and gives a cleaner cut.
- Make sure you cut only timber. This applies particularly when cutting secondhand timber which may contain old nails, and situations where the saw may come into contact with soils, gravels or other materials that are likely to damage the cutting edge.
- Always store the saws in a safe place and keep them clean. The saws may be readily damaged if dropped or banged against other materials. They will quickly rust if allowed to stay moist. Incorrectly stored saws may also be a safety risk, particularly if children have access to the area where saws are left.
- Use the right saw for the job. This will make the task easier for you and produce a better job.

Spades and shovels

Shovels are used for moving loose soil or other loose material. Their blade is cupped and angles inwards from the line of the handle. A shovel is not designed to dig. Spades, where the blade follows the same line as the handle, are used for digging and planting. Spades and shovels can have short or long handles, with the blade curved (round mouth) or straight across the bottom (square mouth).

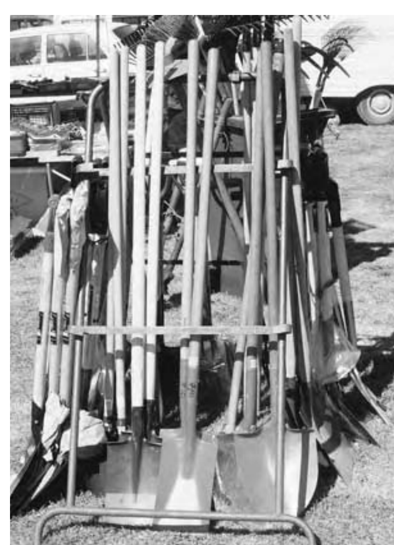

Figure 9.6: It is advisable to keep a range of long- and short-handled spades and shovels, as each tool has a correct application which will help avoid injury.

Long-handled spades provide greater leverage (placing less strain on your back) and greater reach (allowing you to dig deeper holes). They are best suited for digging holes or trenches, particularly in hard clay soils. Short-handled spades are better suited to use in confined spaces or for digging over established garden beds with relatively loose soil.

Forks

Forks are used to cultivate or mix soil, or to move organic material about, such as turning over a compost heap. The prongs of a fork can be round or flattened. Flattened prongs are more suitable for moving organic material about.

Hoes

A hoe is used to cultivate (mix or turn over) soil, which is done to kill weeds or to loosen the soil and allow better penetration of air and water. A long-handled hoe which has a handle the same height as the user places least strain on the user's back. There are two main types of hoes:

- a vertical action hoe, which loosens the soil and chops under the weed. These include single-prong or three-prong hoes, chip hoes and draw hoes;
- a horizontal action hoe, which moves through the soil just below the surface. The top of the weed is cut from the roots by the sharp blade. In the case of annual weeds, there is little if any regrowth and the weed dies. These include traditional Dutch hoes and torpedo hoes.

Rakes

Rakes suffer a great amount of strain where the head meets the handle and, along with axes, are perhaps the tools most likely to suffer from broken handles. The prongs (or teeth) of a rake also suffer a great deal of strain (particularly if being used to landscape a new garden). Rakes vary considerably in construction and type of materials used. The most common types of rakes include:

- grass and leaf rakes – these have long flat tines or teeth that lightly brush the surface, catching light loose material such as leaves and grass clippings. Some better-quality rakes have adjustable rake-head width to cater for differences in the size of the materials being raked. Grass and leaf rakes are generally constructed from metal, bamboo cane or plastic. The metal rakes generally last longer, but may rust unless they are plated. They are also usually more costly. Bamboo and plastic rakes don't have rust problems and are generally cheaper than the metal ones, but are nowhere near as durable;
- nail rakes – in general, steel teeth are riveted to a steel frame. The teeth or tines are rigid and are shorter than those of grass and leaf rakes. This allows shifting of heavier material and allows the rake to have a cultivator-like effect on loose soils. If incorrectly used, the teeth may become loose;
- single-piece rake heads – generally formed from a single piece of carbon steel, sometimes from moulded plastic. This type has similar functions to the nail rake. Teeth size, shape and numbers vary according to the type of work to be

undertaken. For example, you may have 10, 12, 14 or 16 teeth depending on whether you are raking fine or coarse gravel, asphalt or soil. Both nail and single-piece rakes usually have sockets welded to the frame for the easy attachment of wooden handles.

Snap lock tools

There are several modular tool systems with a range of heads that can be connected to or disconnected from the one handle as required. Available heads include rakes, hoes and cultivators, aerators, seed-sowers and pruners.

Major advantages of this system are the space saved in storing tools and the flexibility of being able to vary the length of handle on a tool head. The main disadvantage is greater wear and tear on the handle and locking mechanism, than on any individual head.

Wheelbarrows

When buying a wheelbarrow make sure the centre of balance is over the wheel not on your arms, and that you have plenty of legroom when wheeling the barrow. Choose a solid, well-constructed wheelbarrow. A well-built wheelbarrow will last for several decades if properly maintained. Keep tyres pumped up, grease all moving parts, wash out soil or rubbish after use and store out of the weather. If this maintenance is not done you will be lucky to keep a barrow in use for more than five years.

Machinery

Machines are tools which have moving parts powered by an electric or petrol engine. Machinery can make a dramatic difference to the amount of work a nursery can do. Machines enable simple jobs like cultivation, spraying and moving plants to be done faster and with minimal physical strain on staff. More sophisticated and expensive machines, such as the seeding and potting machines described earlier, can even carry out routine nursery work.

How an engine works

Internal combustion (petrol) engines work by a rapid series of explosions taking place when fuel and air are mixed inside a chamber (or chambers) and ignited. One wall (or part) of the chamber can move – when the explosion takes place that part is forced out, that movement makes other parts of the engine move, and that movement is then transferred to make the engine move where it is required to move. The momentum of the original engine part's movement is aided by a weighted flywheel which returns it to its original position for the next explosion, which then forces it out again, and so on. The fuel used in an engine is generally gasoline, diesel or LPG gas. The same principles apply in the operation with all three types of fuels.

Stages in each engine stroke

Stage 1: Intake
First the intake valve opens. Next the piston moves outward in the cylinder, towards the crankshaft. This causes a partial vacuum. The vacuum then sucks a mixture of fuel and air into the cylinder.

Stage 2: Compression
As the piston reaches the bottom of the cylinder, valves are closed and the mixture is compressed (pressure is increased).

Stage 3: Power
The fuel is ignited by a spark from the top of a sparkplug which screws into the cylinder. This forces the piston up the cylinder.

Stage 4: Exhaust
An exhaust valve opens and the movement of the piston forces gases from the explosion out of the cylinder.

Differences between two-stroke and four-stroke engines

In a two-stroke engine, the intake, exhaust, power and compression strokes of the engine occur in one rotation of the crankshaft. In a four-stroke engine there is more time between this series of events, with the crankshaft making two complete rotations for the four stages of a stroke.

Types of machinery

Tractors
Modern farm tractors are effective and up-to-date agricultural power units. Changes have helped make them more efficient, safe, convenient, versatile and powerful.

There are tractors of all sizes and for every imaginable task. Tractors can be classified according to wheel or track systems, for example three-wheel, two-wheel drive or four-wheel drive. They can also be classified according to use and size, for example industrial tractors, lawn and garden tractors.

Horticultural tractors are machines capable of pulling, carrying and operating a variety of implements and machines. They can be broadly divided into two groups: tractors on which the operator rides, and pedestrian-operated machines.

Figure 9.7: A small tractor can be used for a range of tasks, including towing, slashing and digging in a nursery situation.

New tractors can provide high levels of operator comfort, for example airconditioning and radios in the cabin. These comfort features tend to lessen operator fatigue and therefore improve safety.

The engine is the tractor's source of power, and must be properly coupled to the rear-drive wheels to make the tractor a practical machine. The clutch, transmission, differential and final drive are the parts that make the tractor engine versatile, adapting it to the job required.

The clutch disconnects the engine from its load. There are different types of clutches – those commonly used in tractors are the single-driving plate and multiple-disc type, either hand- or foot-operated. They must be adjusted to ensure the parts run freely when disengaged and will not slip when engaged.

The transmission is a set of gears, providing speed reduction ratios between the engine and the final drive. Some tractors have hydraulic torque converters which permit the forward speed to vary with the load at the drawbar, reducing gear-shifting.

The differential permits the two rear wheels to turn at different speeds while power is being transmitted through both wheels. This is necessary when it is driven on a turn, and the outside wheel must travel further and therefore faster than the inside wheel.

The power take-off shaft (PTO) on a tractor enables power to be delivered to stationary machines as well as to field machines which require rotating power.

The three-point linkage is for the purpose of quickly attaching implements to the tractor. There are three points for connection (if there were only two points used, the tractor might tip backwards). Power from the tractor lifts the linkages.

The type of steering mechanism can vary, though there are some basic parts common to many systems. All wheel tractor steering systems involve a gear reduction unit, most commonly the worm-and-lever mechanism and the worm-and-sector unit. They provide the gear reduction necessary to make steering easy under most conditions. Tractor wheel brakes can also be used to aid steering, as the brake can be applied to one wheel independently of the other wheel.

Steering gears usually run in oil, having a reservoir separate from other tractor parts. Oil must be checked and kept at the proper level. Power-steering units are usually standard on new tractors.

Tree spades

These are specialised tractor-mounted attachments designed to help lift trees which have been grown to an advanced size in nursery rows.

Vehicles

One of the biggest expenses for a nursery (after the cost of the land and buildings) is one or more vehicles to transport plants. Retail nursery managers sometimes need to travel to wholesalers to buy plants or deliver plants to customers. Wholesale nurseries will need to make deliveries to customers.

New small nurseries can often delay this major expense by modifying a tandem trailer and pulling it with the family car, although this is generally only a temporary measure. A tandem trailer or truck which is used to transport plants must be modified to:

- protect the plants from wind – a canopy, preferably one that will totally enclose the trailer, must be provided;
- hold the optimum number of plants – this is often achieved by creating shelving. Pay particular attention to the height between shelves. Ideally, shelving should be adjustable so that heights can be adjusted according to the plants you are carrying;
- take the weight of a full load – there can be a lot of soil in a full load of plants. You should calculate this weight and obtain a trailer or truck which can easily deal with it. If using your car to pull a trailer, make sure the car is rated to pull the trailer when fully loaded.

Mulchers

Mulchers are useful in nurseries for disposing of pruning material and in isolated locations may be a way of chipping material to be used in potting mixes. If the mulcher is to be used in this way, a relatively powerful chipper is needed to chip the material into small pieces, which must then be composted before they are added to the potting media.

Only plant material should be put into the machine, as other material can damage the blades and working parts. These machines are noisy so hearing protection should be worn and the manufacturer's safety instructions should be followed closely. Mulchers should only be operated by adults.

Figure 9.8: Mulchers can be useful for disposing of prunings and other organic material. This small mulcher can be mounted to the back of a tractor.

Cultivators

Rotary hoes and cultivators are used to prepare soil beds for growing stock plants and in-ground production. This type of equipment is very important in advanced tree nurseries, bulb farms or any other nurseries where plants are to be field-grown (in paddocks), then dug for sale.

Rotary hoes are used to loosen the soil, providing a well-cultivated tilth. They can be self-propelled or power take-off driven, tractor-mounted or pedestrian-operated. The self-propelled machines are generally driven by petrol engines and rubber-tyred drive wheels, or by using the rotating blades to pull the machine. Most require a reasonably strong person to operate them properly.

In tractor-mounted machines the large rotors are powered by the power take-off unit. The rotor is a shaft onto which are bolted a series of L-shaped blades that, when rotated, dig into and turn over the soil. Around the rotor is a shield that protects the operator from flying debris and soil clods. The blades rotate in the direction of forward travel, slicing into the ground and throwing the soil into the other blades or against the shield, where it is pulverised.

The small self-propelled units are useful in tight conditions and down to soil depths of 15–20 cm (6–8"), while the tractor-operated versions are more suitable for larger areas and where greater depths of cultivation are required.

Tractor-drawn cultivators come in a wide range of types. Some mix the soil, others cultivate without having much effect on the soil profile. Check the equipment available and make sure you get the appropriate cultivator for the intended use.

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Figure 1: Plant sales at weekend markets can undercut the prices at commercial nurseries and reduce their profitability.

Figure 2: When planning the nursery site, the manager needs to make sure that customers will have easy and convenient access to plant sales areas.

Figure 3: This production nursery collects and uses rainwater from greenhouse roofs.

Figure 4: Newly germinated seed still in seed trays. Many annuals can be propagated quickly from seed.

Figure 5: Growth room for tissue culture plants *in vitro*. Set-ups such as this can allow nurseries to propagate difficult species, but they require a large capital outlay.

Figure 6: Gathering cuttings from *Evolvulus pilosus*. Well-trained propagators can produce many times more plants than other plant producers.

Figure 7: Seeding machine in a large production nursery.

Figure 8: Plants in punnets ready to be potted into larger containers.

Figure 9: Plants being put into tubes to be grown-on for sale.

Figure 10: Westringia cuttings struck in propagation sand ready to be potted-up.

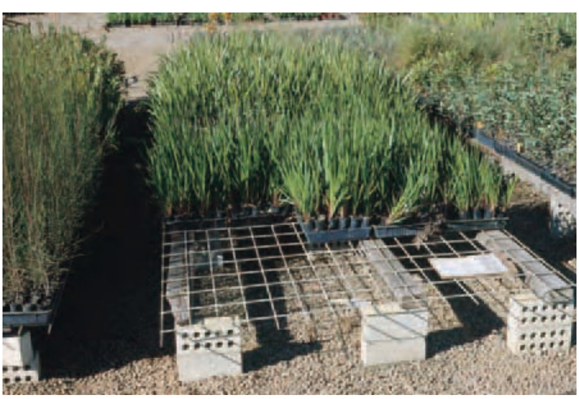

Figure 11: Tubestock allows plants to be grown with very little space between them.

Figure 12: A recycled-fibre pot that will break down slowly. There have been mixed reports on the success of such pots in nurseries.

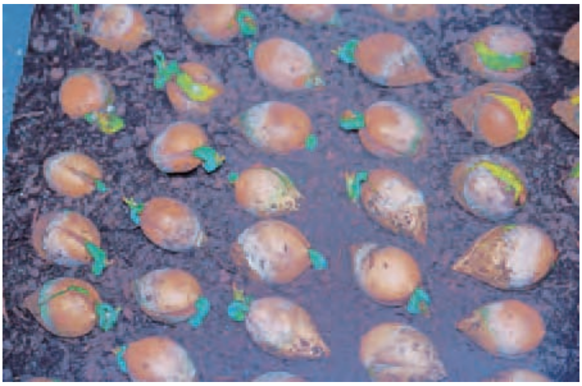

Figure 13: Cycad seed can take a long time to germinate and the plants are slow-growing. This increases the cost of production and drives up the price of the final product.

Figure 14: Grevillea 'Robyn Gordon' is a popular hybrid in Australia, hence many nurseries carry the plant.

Figure 15: Responsible nursery managers must be aware of the dangers of selling potential weeds. Here, impatiens plants have escaped into bushland and the species is now an environmental weed.

Figure 16: Rose breeders are still trying to produce the elusive blue rose. The gene for blue petals has been inserted into a number of different roses but due to the cellular make-up of roses, the blue gene is usually expressed as pink petals.

Figure 17: Knapsack-type sprayers like this are convenient in the nursery as they can be carried to almost any location and are simple to use.

Figure 18: Glyphosate is a common systemic herbicide. The grass on the right shows the effects of glyphosate spraying after two weeks.

Figure 19: Propagation mixes must supply the correct balance of air and water to encourage the developing root system. They must also supply the correct nutrients for a developing plant and be sterile, to avoid diseases and weed germination.

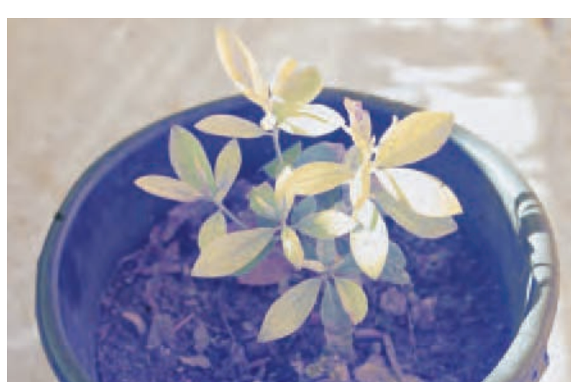

Figure 20: The yellowing on the leaves of this azalea is caused by iron deficiency. Fertilisers such as iron chelate and iron sulfate can help to correct this problem.

Figure 21: A slow-release fertiliser can deliver nutrients over a long period of time. This can reduce the need for very frequent fertiliser applications.

Figure 22: Notice the way in which these plants have been presented in brightly coloured pots. Presentation such as this can sell plants that might appear bland in standard nursery containers.

Figure 23: Some garden centres and nurseries sell pots as separate items. Customers can then choose their plant, pot and potting media to produce something unique.

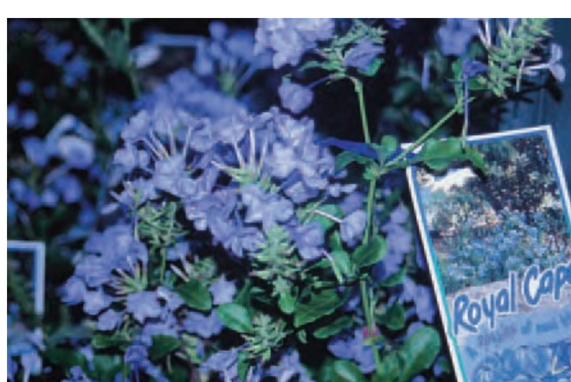

Figure 24: Printed picture labels are visually appealing and can be useful for selling plants when they are not at their best.

Figure 25: A simple greenhouse roof vent.

Figure 26: Plastic-clad greenhouses are widely used in horticulture as they are the least expensive greenhouse structure to build.

Figure 27: This hothouse is heated by solar energy only.

Figure 28: This flat-arched shadehouse has a slight dome in the roof, allowing for easy shedding of water, leaves and other materials.

Figure 29: A simple tunnel shadehouse. These are available in kits and are easy to construct.

Figure 30: The panels of this glasshouse have been whitewashed to reduce light transmission during a hot spell. The whitewash can be removed easily when the weather cools.

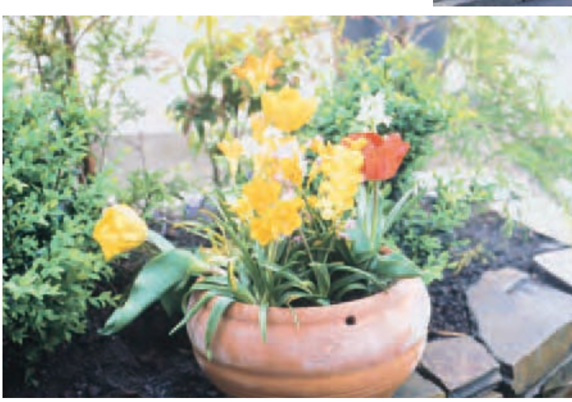

Figure 31: Collections of flowers can be marketed as a gift for special occasions such as Valentine's Day and Mother's Day.

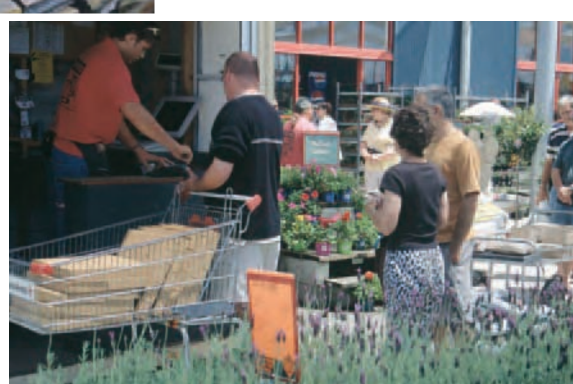

Figure 32: Customers shy away from cluttered and confined spaces. When setting up the nursery, consider the effect of space on customers' behaviour.

10

Irrigation

A water management program is an important aspect of nursery management, not only to ensure that plants receive adequate water but also to ensure that the risk of overwatering and water wastage is kept to a minimum. A water management system should take into account many different factors, including climatic conditions, the plant species being grown, disease risks, water application rates and whether the plants are container- or field-grown. The availability of a constant, good-quality water supply is imperative when selecting a nursery site.

Water supply

The supply of water for any nursery must be of good quality, available in a reliable quantity and at an affordable cost.

Water is becoming an increasing costly commodity, which for nursery operators means that the cost of production increases accordingly. Long periods of dry weather can lead to water restrictions – unlimited supply is not always guaranteed. It is prudent to ensure that your watering program is carefully considered to reduce waste. For example, up to 80% of water from overhead sprinkler systems is wasted.

Many nursery owners try to overcome this problem by keeping their own dams or tanks. Water is available from a number of sources.

Town water supplies

As populations grow and industrial/residential demand for water increases, the availability of town water for horticultural uses such as nurseries can be restricted. Being accessible now doesn't mean that it always will be. Town water can be expensive in some cities, with excess water bills a major part of nurseries' running costs. This is offset to some extent by being close to customers, hence avoiding having to spend money on transporting plants great distances to markets.

Rivers, lakes and streams

Flowing water such as rivers and streams are usually relatively free of contamination, but there are exceptions, depending on what is upstream. The closer you are to the source of the watercourse, the better quality the water. Properties located close to a permanent and accessible water supply such as this are ideal nursery sites. The water quality must be considered, though. Even if the quality is good now, it might not always be. Check whether streams and rivers dry up. Check the permits required to pump water from the watercourse, and the cost of pumping equipment.

Groundwater (bores or wells)

Many sites have groundwater that can be pumped from a drilled bore, but the quality of groundwater can vary greatly. In some places it may be too salty to use on some or all plants. Some nurseries mix better-quality water from another source with bore water to get a tolerable level of salt and hence increase the quantity of water available to the nursery. Modifying the type of potting mix used can also help reduce the effect of bore water with some level of salt.

Before using bore water it is a good idea to have it laboratory tested and carefully consider the results. Bore water doesn't always remain the same. If there are too many bores in your area, or if there are significant changes to the soil environment such as earthworks, tree clearing or altered drainage patterns, the amount or quality of bore water can change. Testing should be undertaken on a routine basis, at least every six months. Bore water is unlikely to have physical impurities but it commonly contains salts causing hardness, alkalinity, salinity or corrosion to pipes, metal benches and tools, and storage tanks etc. There are rarely any significant biological impurities, but there may be some.

Figure 10.1: In areas with sufficient rainfall, rainwater can be stored in tanks. This method of supplying water may involve higher initial costs but in the long term can be cheaper than buying water.

Rainwater

In areas that have sufficient annual rainfall, water can be collected into storage facilities such as dams or tanks. This method of supplying water involves higher initial costs, but in the long term can be less expensive and perhaps more dependable. The annual rainfall does not need to be spread evenly throughout the year; if it is, the cost of storage will be less as you will be able to install smaller tanks and count on constant refilling.

It can become expensive to pump water to the plants, so the location of the storage facility has to be considered carefully. If the water is above the main plant area, it may be possible to position the storage high enough to gravity-feed the water. Water that is not fed by gravity will have to be pumped.

When storing water, not only does it cost money to build the storage facility, but a dam or tank also occupies space which might otherwise be used to grow plants. Where land is expensive or space is limited, some nurseries have constructed below-ground water storages. Below-ground storage has the added benefit of insulating the water against the weather which can make the water icy-cold in cool-climate winters or excessively hot in warmer climates over summer. Excessively hot or cold water may actually slow growth when applied to plants. Water stored below the floor of a greenhouse gains the benefit of being cooled or warmed by the environment in the greenhouse.

If water storage is used only to supplement other water supplies, perhaps as a back-up in drought or for higher-quality water needed for propagation, consider the quantity of water you are likely to need for the year, and the rainfall patterns, then determine your storage needs accordingly. In some tropical or subtropical areas, the annual monsoon rains deliver huge quantities of water over a few days or weeks, followed by dry periods of many months. Other climates are prone to drought every few years. Such areas may require water storages that are sufficient to last twelve months without any further supply.

Water quality

Water quality affects the quality and rate of plant growth both during propagation and later when growing-on in the nursery. Every source of water is continually changing – if your nursery has good-quality water today that doesn't mean it will be good next month. The quality of water should be monitored at regular intervals; if quality is suspect the intervals should be frequent. Ideally, nursery water should be free of all types of contaminants including salts such as minerals or fertiliser residues, dust or soil particles and biological contaminants such as pests and diseases.

Storage systems

Concrete pits are expensive but permanent water stores can supply very clean water. Fibreglass, plastic or metal tanks also supply good-quality water.

An earth dam is usually cheap to build, but the soil must be appropriate. In some sandy soil types it may be necessary to put a layer of more appropriate soil over the base of the dam, or to use a water-impermeable liner.

Salinity

Salinity occurs when there are high concentrations of salts in the water. Salinity can be determined by using an EC (electrical conductivity) meter, available from hydroponics suppliers.

Hardness

Excessive levels of calcium or magnesium in water are referred to as hardness. This makes lathering of soap difficult and leads to formation of scale or crust, particularly in pipes and water heaters, reducing their efficiency and life.

Contamination

If drainage from the nursery or neighbouring properties goes into the storage, water may become contaminated with fertilisers, chemicals or even diseases which can then be spread around the nursery when you water.

Water that is shallow, exposed to light and contains some nutrients will likely grow algae or other weeds. It is important to develop an appropriate ecological balance of animal and plant life in dams if water quality is to be maintained.

It is unlikely that rainwater will contain significant impurities, though acid rain does occur in some countries and rainwater which is collected from paddocks, drains, roofs and gutters may be contaminated as it makes its way to the storage.

Water treatment

If water quality is poor due to physical, chemical or biological contaminants, it may be necessary to treat water before using it in a nursery. Some nurseries collect and recycle waste or runoff water, then reuse it. This is fast becoming an environmental and legal obligation for many nursery owners.

Treatment of irrigation water is usually carried out through one of two methods:

- through an active system that relies on chemicals, heat or microfiltration to remove or destroy the plant-pathogenic fungi and bacteria. This method also changes or even destroys the microflora. It can leave chemical residues, some of which can affect water quality by raising salt levels;
- through a passive system where the chemical properties of the water are not changed and there is a stable population of microflora which suppresses disease organisms.

Oxidation

Aerating water by installing bubblers or fountains increases oxygen and reduces algal growth. Some propagators say aerated water is better for propagation.

Chlorination

Chlorination does not affect crops, unless the chlorine is greater than 0.4 ppm. Chlorine added to town water is mostly volatilised or changed to safe chloride by the time it reaches the greenhouse bench.

Fluoridation

Fluoridation does cause injury to some crops. The 0.5–1 ppm added by some council authorities to reduce tooth decay will injure some green plants, such as species of the genera *Chlorophytum, Cordyline* and *Dracaena, Maranta, Kerchoviana* and *Spathyphyllum*.

Ultraviolet light
This only works if the water is clear enough that the UV light can penetrate.

Microfiltration
Suspended solids can be removed by micromesh filtration.

Slow sand filtration
Slow sand filtration (SSF) is used for treating recycled water. This reduces the likelihood of biological growth such as algae and harmful bacteria, and at the same time optimises the development of suppressive bacteria. The suppressive bacteria destroy plant pathogens during the slow filtration process. This has been a very successful system in the greenhouse industry, and container nurseries that use large volumes of water are also beginning to implement the system.

Sand filtration removes silt and doesn't remove clay or bacteria. However, biological organisms can grow in the filter and shock disinfection may occasionally be needed. Filters are usually constructed as part of holding ponds or dams, or sometimes tanks are used. The bacteria population in the filters and disease presence in the irrigation water are carefully monitored.

Reed beds
Planted reed beds are also used to treat water, aiding the disposal of water with high nutrient content or other contaminant. Water evaporates from reed beds about ten times faster than from an open body of water, making them a very efficient way of disposing of poor-quality water unsuitable for recycling and excess water during times of high rainfall.

The reed beds need to be fed effluent to support their activity, as relying on nutrient runoff alone is insufficient to keep the micro-organisms living on the root systems active. Reeds can also be used in ditches and containment dams or ponds in nurseries to increase suppressive infiltration systems.

Recycling water
The most important aspect to saving water and reducing water runoff and contamination from nutrient leachate is to design and implement an efficient irrigation program in the first instance, or improve the efficiency of an established system. A well-designed water-wise system will help to reduce the volume of wastewater and therefore reduce wastewater runoff, nutrient leachate and the need for a recycling system.

Nursery operators should be aware that legislation can force nurseries to control and even change production systems and practices that cause pollution to waterways. This includes the necessity to collect, store and treat wastewater. It therefore makes sense to implement a program that minimises water and nutrient usage in the first instance. Nurseries that have implemented a recycling program have reduced their water usage by around 50%. This figure can be reduced a further 20% with use of capillary mats and a further 10% if capillary mats are used in conjunction with drippers.

The apparent contradictions in a nursery's requirements to produce quality plants using a low-cost system, as well as implement a production system that is environmentally responsible, can largely be solved by using a recirculating system optimised to suit individual nurseries. This type of system could consist of:

- sealed beds that are well-drained and collect the irrigation water;
- collection ditches at the bottom of the beds;
- a storage area in the form of a tank, pond or dam suited to the size of the nursery;
- an irrigation scheduling system designed to reduce water loss and capture the lowest possible amount of recycled water.

The use of nutrients in nurseries should also be examined. Nurseries should implement a program that minimises the use of fertilisers, especially nitrogen, as this in turn will minimise the leaching of nutrients into wastewater. The quality of the wastewater collected for recycling will thus be better and require less treatment before reuse.

Recycled water has very low volumes of pathogens, due to dilution, in nurseries where large volumes of overhead irrigation water are used, and recycled water is stored in large-capacity dams that also regularly have large volumes of water pumped into them. Reeds and other water plants along the banks aid the biological activity but no chemical form of disinfection is needed.

Irrigation systems

All plants require water. How they are watered depends on how the plants are grown. Field-grown plants, for example, are usually watered by travelling or fixed sprinklers and may or may not be watered daily depending on the prevailing climatic conditions. Container-grown plants usually need daily applications of water, due to the root restriction within the pot. The size of the root zone is often small compared to the size of the plant and therefore water is rapidly taken up by the plant.

There are three main types of irrigation systems used in the container nursery industry:

Figure 10.2: Tunnelhouse, showing overhead irrigation line.

overhead sprinklers, micro-irrigation and sub-irrigation. Overhead sprinklers may be fixed or travelling. Micro-irrigation may include the use of various types of drippers, micro-sprayers and misters. Sub-irrigation may involve periodic flooding of plants, or capillary mats. Occasionally there may also be a need for hand watering.

The considerations when choosing an irrigation system depend on the type of nursery, the way in which plants are grown and the economic restrictions. In all cases, the best irrigation system is economical, efficient and application-specific. The irrigation system can be manually operated, semi-automatic or fully automatic.

Automatic irrigation systems

Irrigation can be controlled automatically by sensing devices which switch the watering on when it is needed, or by clocks which switch the watering on at the time and for the length of time specified. Automatic systems can require resetting when conditions change throughout the year. They can also break down, and watering might be missed without you noticing. It is important that you do not rely on automatic systems – frequently check their operation and the way they are affecting the plants.

Fully automated systems can also include remote control devices and access via the internet, telephone or mobile phone, allowing you to override a set program during specific climatic conditions, or be alerted to a power failure.

Any type of system must be well-designed to the needs of the nursery and hydraulically sound to ensure uniformity of water application and distribution. To apply such a system and achieve best efficiency, nursery managers should have a sound understanding of:

- irrigation scheduling;
- plants' water requirements;
- the media water-holding capacity;
- the capabilities of the system.

Overhead sprinklers

Sprinklers have been widely used in the nursery industry, for both container-grown and in-ground plants. There are some very good reasons for this:

- reliability;
- low maintenance;
- frost protection;
- chemical injection.

However, overhead sprinkling is an inefficient system due to excess water usage, runoff, the cost of recycling water, lack of uniform application, and the need to correctly space and group plants. The average efficiency of overhead sprinklers is around 25%, meaning that approximately 75% of the water is lost. This figure can be even higher in nurseries that also water pathways and roads. Nurseries that situate pots on concrete pads with the runoff collected and recycled can reduce water loss, but the cost of this and the extra land needed may make a micro-irrigation system a viable alternative.

There are two types of sprinkler head:

- spray head – this head does not have moving parts. Water is sprayed over the total area all at once, whether in a full circle, part circle or some other shape. These sprinklers cover relatively small areas;
- rotating head – this sprinkler has moving parts. It squirts a stream of water in one or several directions, and rotates, spreading the water as it moves.

Sprinkler placement

The type and placement of sprinkler heads is critical to achieving a uniform coverage of water. Different types of sprinkler heads deliver water at different rates and cover different areas. The precipitation rate is normally expressed as inches or millimetres per hour, and can vary up to 400% between areas covered by the same sprinkler system. This means that plants in one area may be severely underwatered while plants in another area may be severely overwatered.

A sprinkler often does not distribute water evenly over its full radius. Water is usually distributed evenly over the 35% of radius closest to the sprinkler head, but the amount of water distributed beyond this point decreases. The distribution of water to the outer edge of the radius can drop even more in windy conditions. Prevailing winds should be considered when deciding where to place sprinkler heads.

Sprinklers water a circular area or, if there is a wind, an oval shape. If sprinklers which water a radius of 10 m (33') are placed 20 m (66') apart, the outer edges of water-cover from each sprinkler may meet, but there will be patches without water cover. If the two sprinklers are moved closer, some areas will receive water from both sprinkler heads and other areas will receive cover from only one sprinkler head.

Considering that sprinklers generally deliver an even cover for only 30–35% of their radius, sprinkler heads are normally spaced close enough to achieve as even an overall cover of water as possible. Water will penetrate deeper in areas which receive a heavier application of water because they are closer to a sprinkler head, or because of overlap between two sprinklers. In areas which get less water, the penetration may be shallower and plants may not grow a deep root system, for example. Smaller sprinklers and heads which water only part of a circle can be used effectively for watering odd-shaped places.

Micro-irrigation

In micro-irrigation, water is delivered directly to the root zone of plants. This gives it an advantage over most other systems in specific applications and is particularly beneficial for plants that are prone to fungal disease caused by wet foliage, such as roses. Micro-irrigation systems are also suitable where chemical application is done through the irrigation process (chemigation). There is less leachate and water runoff from pots that are micro-irrigated. The system is particularly suited to advanced plant production, particularly when plants are grouped together and not moved for lengthy periods.

Figure 10.3: These chrysanthemums are watered by drip irrigation, which reduces the risk of leaf problems by delivering water to the root zone of the plants.

The micro-irrigation system involves a slow dripping of water at each point and is extremely efficient, with less then 10% of water being wasted. More then one dripper may be required to evenly distribute water through large containers. Although the design varies greatly, the basic components of all trickle systems include an automatic controlling device, a pressure regulator to ensure water pressure is even between drippers, system filters, control valves, and drippers or microsprays.

Advantages of micro-irrigation

- Conserves water – water is directed at the roots, exactly where the plant needs it most. Loss of water from wind and excess runoff is minimised, saving on water rates and conserving increasingly scarce water supplies.
- Saves labour – although trickle systems are time-consuming to set up and occasionally require ongoing maintenance, they are permanent fixtures which can be fully automated. Busy work schedules and holidays are no longer a problem with such a system.
- Efficient placement of water – people, paths, furniture etc. close to the water outlet aren't wet when the system is on.
- Reduces weeds – weeds have less chance of germinating because less soil area is moist.
- Reduces disease – trickle systems don't wet the foliage and flowers. Wet foliage and flowers are more susceptible to diseases.

Disadvantages of micro-irrigation

- In well-drained growing media, there is little horizontal movement of water in the soil, as water moves straight down away from the root zone.

- Salt, shown by a white caking, can build up in the area where the water is applied.
- Some research indicates that root development is restricted to the wetted area, particularly with larger plants.
- If trickle irrigation systems are to operate properly without serious blockage of the fine water outlets, periodic maintenance is necessary. Generally this involves cleaning filters, flushing and chlorinating the system.

Sub-irrigation

This involves water soaking up into the bottom of plant pots or trays. Such capillary watering supplies a constant supply of water to plants without needing to wet the foliage. The number of times water needs to be applied is reduced to however often the supply below the plants needs to be replenished. There are several ways in which water is supplied to pots through capillary irrigation.

Ebb and flow

This system of irrigation is becoming popular, particularly in nurseries that produce flowering pot-plants. Production rates are very high, with thousands of pots all the one size and containing the same species, therefore water requirements can be reduced. The plants are set in shallow trays or basins that are periodically filled with a few centimetres of water for a set period of time.

Capillary mats

Capillary mats are used by large-scale wholesale production nurseries. The mats are set into metal trays or beds that are irrigated by drip lines. Tensiometers, placed directly on the mats, monitor humidity.

Outdoor sand beds

Outdoor sand bed irrigation is a simple manual, non-electric system developed in the UK. Bed widths must be narrow so they can be reached from either side to prevent compaction caused by walking on wet beds.

Waterwell pots

Waterwell pots are an extremely simple watering method that can be used for individual plants or for very small quantities. A reservoir of water is attached to the bottom of a pot. As the plant uses water and the potting mix dries, it is replenished by water soaking up through the bottom of the pot.

Hand watering

Watering by hand, with a quality watering-can, allows you to deliver water where it is needed and in the required quantity, which may vary from plant to plant. However, with hand watering the water is not always targeted at the soil, and the foliage of the plant is also watered. This can result in a lot of water wastage as well as spreading disease in some species. Water can damage the foliage or flowers of some plants more than others, and in some climates it may encourage pest or disease problems if it isn't kept away from the foliage. Hand watering is a very expensive way to water and is only economically viable in special circumstances.

Nurseries use watering-cans for various tasks. When used to water-in cuttings immediately after planting or seed immediately after sowing, the can must deliver a gentle and even supply of water. Inexpensive watering-cans can sometimes drip or lose their rose, damaging the pot or tray you are watering. Cheap alternatives are simply not worth the risk.

Watering-cans are also used to hand water particularly valuable plants, or in situations where it is important not to get water on foliage or flowers. High-value plants such as bonsai or rare plant varieties may be watered this way. Some nurseries which are renowned for growing top-quality plants such as african violets or pelargoniums use hand watering either all of the time, or for a period prior to selling the plant. This way they avoid marks on foliage or flowers. Retail nurseries may use hand watering for the same reason exclusively on some types of plants.

Figure 10.4: The plants in this tunnelhouse are watered by hand.This may be time-consuming, but it allows the nursery manager to deliver the water when and where it is most needed.

Pulse watering

This can be used to get a deeper penetration of water where water lost due to runoff is excessive. Pulse watering involves shorter and more numerous irrigation periods. For example, instead of watering for half an hour daily, it might involve a 5 minute watering followed by a 15 minute break, then another 5 minutes of watering and another 15 minute break. This might be repeated twice more, giving a total 20 minutes of watering. In many cases, pulse watering results in greater water penetration, less wastage through runoff and a good result with less use of water.

Demand irrigation

This system is useful for field-grown plants, advanced plant production or trays of pots. Each pot, bed or tray has a sensor/probe that measure the soil's moisture content. The sensor is linked to a receiver that automatically triggers the irrigation solenoid.

Precision irrigation

Nurseries that have large production runs of similar-sized containers often develop specific precision-controlled irrigation methods. These methods include:

- travelling boom sprayers that have been adapted to greenhouse use or outdoor sites. They have the advantage of applying water close to the pot or crop, are set to ensure that aisles are not watered and reduce water loss from wind drift and evaporation;
- in-pot sprinklers, drippers and bubblers that are often used in large pots, such as in advanced tree production where plants are in pots for lengthy periods.

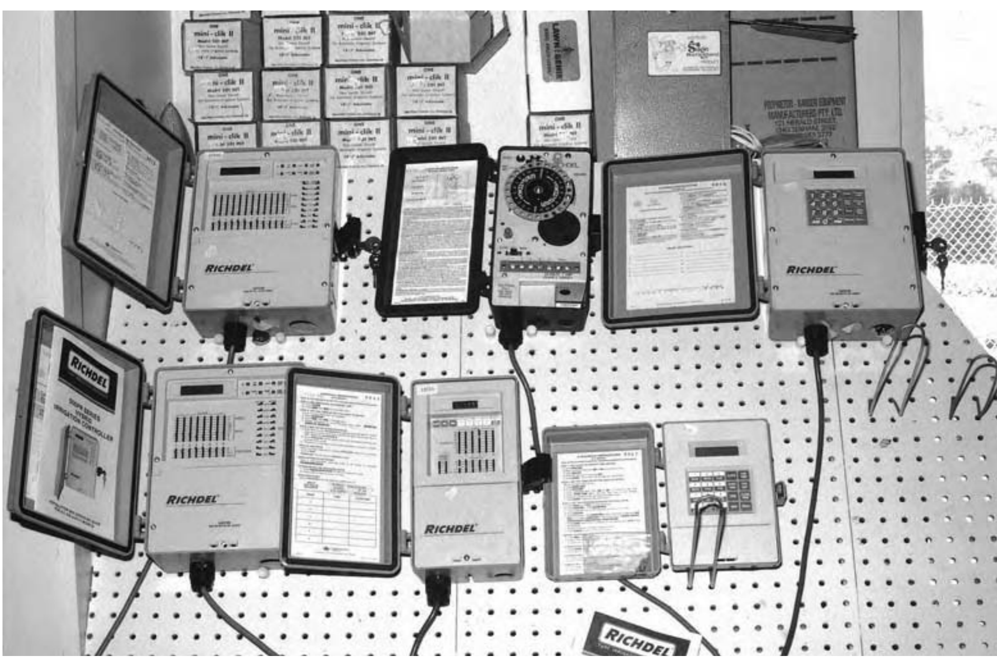

Figure 10.5: These irrigation controllers are suitable for large systems and automatically operate the irrigation system according to the specified settings.

Pumps

The purpose of a pump is to create the pressure needed to supply water at the required rate and in the required quantity. Before employing a pump you should utilise gravity in all possible ways. That is, using gravity to force water flow is preferable to using a pump.

As well as supplying water to plants, pumps are also used for tasks such as misting greenhouses and pressurising sprayers to spray chemicals. The same factors must be considered, regardless of the pump type being purchased.

- What type of irrigation system do you have?
- What are the suction conditions?
- How often will it be used?
- How reliable must it be?
- How much will it cost?
- Is there a nearby source of power?
- Is it cost-effective to run?
- Will you need to build a pumphouse?
- Is there easy access for maintenance and repairs?

Water flow and pressure

Before deciding what type of pump to use in a system, you must determine the pressure and flow of water required at peak demand. In other words, at what rate do you want water to be supplied when the pump is working at its maximum? The pressure created by the pump must be sufficient to lift water from the lowest point of water supply to the highest point of water application.

Water flow is the volume of water that passes through a pump, pipe or fitting in a given time. Pump flow is measured in gallons per minute, litres per second or litres per minute. Conversion rates are as follows:

- 1 gallon per minute = 4.6 L per minute;
- 1 L per second/60 L per minute = 13.2 gallons per minute.

Water pressure is the force exerted by the weight of the liquid over a given area. Pump pressure is measured in metre head of water, pounds per square inch (psi) or kilopascals (kPa). Conversion rates are as follows:

- 1 psi = approx. 7 kPa;
- 1 meter head = 9.81 kPa;
- 1 meter head = approx. 1.4 psi.

Suction performance

Pumps are usually located above the water source and a short length of pipe is used to draw water into the pump. This is the suction pipe, and the difference in height between the water surface and the pump is the suction lift.

A pump takes water from the source by removing air from the pipe and creating a vacuum. It does not actually suck the water in. Atmospheric pressure does the rest, pushing down on the water surface and forcing water up the pipe to fill the vacuum. Because atmospheric pressure provides the driving force there is a limit on how high water can be lifted, which does not depend on the amount of energy put into the pump. At sea level, atmospheric pressure is approximately 10 m head of water, which is the pressure of the water as it leaves the pump. In theory, it can push water up to 10 m.

Cavitation

Cavitation can decrease efficiency and performance in motors via the formation and collapse of vapour bubbles through the boiling of liquid in water. The absolute pressure of water can be reduced to a point where these bubbles are formed without actually heating the water. Bubbles are carried by water to regions of higher pressure in the pump, where they collapse. This can cause pitting when the bubbles collapse near a metal surface.

Cavitation can be avoided by following the manufacturer's instructions on siting the pump, so that it does not need to raise water higher than the limit of suction lift.

Pump characteristic curves

The centrifugal pump characteristic curve is a graph that shows the differential pressure or head developed by the pump, and also the speed, power and cavitation susceptibility (or limited suction lift). The lower the pump head, the higher the flow rate. In order to obtain the pump's operating point on the curve, the pump duty (performance required) must be calculated. The pump duty describes both the flow rate and the total pressure (head). The data can then be used to determine the pump's position on the curve and therefore whether the pump is suitable for specific irrigation needs.

When a pump is installed it should be tested to ensure that the flow rate and head are within the required specifications. Pumps come with a manual that usually contains a graph showing the pump characteristic curve. The test should correspond with the information provided by the pump manufacturer.

Types of pumps

Pumps are usually either:

- shallow well pumps that raise water up to 7.5 m (25'). The pumping mechanism uses suction to lift the water from below the level of the pumping mechanism;.
- deep well pumps that raise water to heights greater than 7.5 m. In this type the pump is actually immersed in the water being pumped.

The different types of pumping mechanisms are piston, centrifugal, turbine and jet. The pumps are classified according to how energy is given to the water.

Piston pumps

Also called force, reciprocating or positive displacement pumps, these work on a plunger principle. That is, a plunger or piston, moving inside a sealed cylinder, creates the water pressure. The simple windmill pump delivers water only on one stroke. The double-acting piston pump delivers water on both forwards and backward strokes.

This type of pump is best suited to small irrigation systems that require pump discharges of no more than 2 L per second, for example nurseries with drip or mist irrigation systems.

In piston pumps:

- a high pressure is produced;
- because water delivery surges, an air chamber is incorporated to even out the flow;
- flow is smaller than other types of pumps;
- excellent suction performance up to 7.5 m in height;
- there are higher maintenance requirement than other pumps;
- transmission needs to be organised for suitable speed reductions to be achieved;
- needs to be able to cope with high loads when starting up.

Centrifugal pumps

Centrifugal (rotodynamic/volute) radial flow pumps can deliver high efficiency against comparatively high pressures. This is the main reason why this type of pump is chosen for commercial sprinkler irrigation purposes.

These pumps are simple in construction, with the impeller and the shaft (housed in the volute) being the only moving parts. They can be installed with the shaft vertical or horizontal. The size of pump is determined by the internal diameter at the discharge outlet. Pumping is achieved by a rotating disc or wheel with attached blades known as vanes, which continuously sling water as the wheel rotates, thereby giving energy to the water.

The pressure and rate at which water flows through the pump depends on the speed and size of the impeller. There are many models, designed for many different purposes. It is important to select the right one for the right purpose. The advantages of the centrifugal pump include:

- installation can be above the water surface;
- less likelihood of damage, as above-ground installation makes it easy to remove the pump during floods;
- less damage from corrosion;
- portable if required;
- inexpensive to maintain and install.

Turbine pumps

Turbine pumps are both mixed-flow and radial-flow (centrifugal) pumps which direct water to the discharge outlet with diffusion vanes that work by rotating an impeller inside a bow. These pumps are most often used for pumping from bores and therefore, unlike volute pumps, there is a limit on impeller diameter and the pressure which can be developed at a given speed. Extra impellers are added when high pressure is required. Turbine pumps are driven by a submersible or a line-shaft electric motor mounted below and coupled to the pump. The advantages of the turbine pump are that:

- it can be driven by an engine when used in bores;
- it is less prone to damage in the water then an electro-submersible pump;
- it is easy to maintain;
- it can be used for very high pressure capacity compared to centrifugal pumps;
- it can be used with water supplies that require long suction pipes;
- it can pump salt- and silt-laden water, unlike the electro-submersible pump;
- the drive shaft can be extended to enable the prime mover to be mounted above flood level.

Electro-submersible pumps

These are turbine pumps with an electric motor. The motor is underneath the pump and close-coupled to it, keeping the unit submerged. As the motor is cooled by the water pumped, power failures can result in damage. The dimension of the pump (length compared to diameter) makes it suitable for use in bores. The advantages of the electro-submersible pump are:

- a short drive shaft;
- it can be installed in a bore that is misaligned;
- it can be installed in waterways subject to flooding. Because the pump has no above-ground working parts, the starting equipment, meter and transformer can be placed above flood level.

Jet pumps
Jet pumps, also known as single-stage centrifugal pumps, are fitted with an assembly called an ejector. This allows the pump to draw water from depths that a conventional centrifugal pump cannot manage. However, due to their poor discharge they are inefficient when used in high-pressure situations.

Variable-speed pumps
Although variable-speed pumps are costly to buy they are much cheaper and far more flexible to run then traditional pumps with a fixed-speed motor. This has the advantage of allowing operators to service a range of irrigation applications.

Nursery operators with irrigation requirements ranging from a small greenhouse to large field production may choose to combine the variable-speed and fixed-speed pumps to give even greater flexibility to their irrigation requirements. The pumps are installed to operate in a parallel system and may consist of two or more pumps; extra pumps can be added if need increases.

Pump maintenance

A pump can lose performance through wear, tear and corrosion created by everyday use. Factors such as water quality, pump design, regular maintenance, whether the correct type of pump is used for the irrigation rate, volume and pressure required of it, as well as the pump quality, all affect a pump's working life.

To help prolong the working life of a pump as well as increase power and irrigation efficiency a regular maintenance schedule, carried out by a professional if necessary, should be implemented as well as:

- choosing the right pump for the job in the first place;
- correctly positioning the pump to facilitate suction performance and reduce the likelihood of cavitation;
- ensuring that there is no movement of the pump during operation;
- ensuring that the motor is well-ventilated;
- checking all pipes regularly to ensure that they are tight;
- ensuring that the pump and motor are aligned;
- cleaning strainers and filters on a regular basis;
- following the manufacturer's recommendations in relation to use, performance and servicing requirements.

Scheduling irrigation

Wilting point and field capacity

Wilting point is the point at which the soil is so dry that the plant begins to wilt. Plants should never be allowed to get to this point. Field capacity is the point at which the soil is holding as much water as it can without excess water draining away and being lost. The zone between wilting point and field capacity is important, as plants should be kept within these moisture levels when irrigating.

Generally plants take most of their requirements from the upper half of the root zone and as a result only about half of the available water is used. Irrigation is therefore required when approximately half of the available water is used up. The amount of water to be applied to plants is half of the available water in the root zone when the soil is at field capacity.

Application and infiltration rates

Irrigation applications should be timed according to how quickly the plants use the available moisture. This depends on climatic conditions and the availability of nutrients. The rate at which water is supplied by irrigation is also affected by soil infiltration rates – the rate at which water will pass into the soil. If water is supplied at a rate greater than the ground can absorb it then runoff may occur, resulting in a loss of water.

The ideal is where application rates are equal to infiltration rates. Infiltration rates can be affected greatly by soil compaction, which causes a reduction in pore space and hence the space available for water and its passage. Before scheduling irrigation, the nursery manager should know the:

- water flow rate of the entire irrigation system;
- precipitation rates of the individual irrigation fittings;
- infiltration rate of the soil or growing media;
- available water held in the soil per centimetre/inch of soil depth;
- average daily evaporation;
- depth of the root zone.

Water conservation

Many nurseries implement water-efficient systems such as capillary irrigation, ebb and flow irrigation and drip irrigation. These types of systems also help to minimise nutrient runoff that has been a major cause of pollution to waterways. Other practices that minimise runoff and water wastage include:

- watering according to the needs of individual plant species;
- irrigating according to seasonal evaporation losses;
- watering according to the water-holding capacity of the potting media;
- placing together plants with similar watering needs;
- situating plants to maximise water penetration and minimise waste between the pots;
- using the pulse irrigation method of applying water, to slow the infiltration rate;
- minimising the use of fixed overhead sprinklers;

- understanding the nutrient requirements of your plants during their growth cycle and the composition of fertilisers used, so that you can implement an appropriate feeding program;
- plugging sprinkler heads that are not watering plants;
- situating sprinkler heads as close as possible to plants and using larger droplet size;
- installing rain sensors for outdoor stock, pressure regulators, soil sensors, wind sensors etc.;
- maintaining existing irrigation equipment at optimum efficiency by replacing washers as needed, checking for leaking pipes, hoses and sprinklers;
- adjusting controllers regularly to suit seasonal changes;
- cleaning spray heads to ensure uniform water distribution.

Maintenance of watering systems

Regular maintenance of a watering system will increase both the efficiency of water distribution and the life of the system.

Plastics

Plastic components will eventually deteriorate through exposure to ultraviolet rays. Replace parts which show signs of splitting, old age etc.

Metals

Prevent rust formation on metal components and treat any parts that are beginning to rust. Flush out galvanised pipes regularly to prevent the build-up of sediment.

Rubber

Rubber seals will perish, particularly when exposed to UV light. Check and replace rubber seals and fittings regularly.

Filters

Filters, particularly in trickle systems, should be flushed out regularly to prevent blockages due to build-up of soil particles or algal growth. This includes the whole filter, both body and housing. Inspect filters for any failures or holes in the mesh then back-flush until clean. Once the filter is clean, flush the entire system including all pipes and nozzles from the mains water supply. Leave the end of each pipe open until water flows from it.

Automatic controllers

Automatic controllers should be tested every few months. Make sure that clocks, solenoids, back-up batteries etc. are all working properly.

Clearing blockages

If blockages do occur in the irrigation system, flush the affected area with a chlorine-based solution such as liquid sodium hypochloride. Use 10% chlorine to destroy bacteria. The entire system should be shut down for 24 hours to give the chlorine time to break down any deposits in the system. After 24 hours, open the ends of laterals and turn on the pump to flush out the dispersed sediment. Close the ends of laterals when the water runs clear.

11

Glasshouses, shadehouses and other nursery structures

Nurseries can include a variety of structures used for specific or multiple functions. These can include buildings to store materials and equipment safely or protect them from the weather, buildings to work in (such as potting sheds), greenhouses and shadehouses to provide ideal environments for propagating and growing plants, structures or buildings for display and selling, lunchrooms, dispatch areas and offices. The choice of what buildings and structures to include in a nursery depends on a variety of factors, including the requirements of the plants being grown and sold, available funds and the range of services provided.

Greenhouses

In order to choose the right type of greenhouse structure and thereby increase its efficiency and productivity within a specific nursery environment, it is important to be aware of the many designs available, and to understand the advantages and disadvantages of each design.

Greenhouses are normally used for one or more of the following purposes:

- to propagate new plants by providing the ideal conditions for seeds to germinate or cuttings to initiate root growth;
- to grow tropical plants in cooler climates;
- to protect cold- and frost-sensitive plants;
- to grow vegetables, cut flowers or berry fruits out of season or faster than might be achieved outside;
- to grow nursery container plants over winter when there may not be much growth in the outside environment;
- to provide a contained growing environment in which CO_2 enrichment is carried out to increase yields;

- to provide a contained and isolated growing environment for plant breeding or quarantine purposes.

Figure 11.1: Glasshouses allow you to control the environmental conditions of plants.

Types of greenhouses

Many different types of greenhouses are available, each with advantages and disadvantages. Generally speaking, the old adage applies: 'You get what you pay for'. Less-expensive greenhouses generally don't do as good a job, and normally don't last as long as costlier structures. Some of the more expensive greenhouses can last a lifetime and will, in many respects, do a better job; however, the initial cost may be a significant deterrent.

There are three common designs for commercial greenhouses.

Gable or even-span

This type is generally used with inflexible covering materials such as glass. The straight-sided walls make it easy to use the entire floor space.

Igloo

A hemispherical cross-section makes this the best shape for light transmission (less sunlight is reflected). This form is also the most efficient in terms of the amount of covering material required and volume enclosed. However, the curved sides make it difficult to use the space as fully as is possible in straight-walled greenhouses. Also, only more flexible materials such as coreflute, polyflute and PVC film can be used on igloos.

Raised arch

In this compromise between the gable and igloo shapes, straight sides carry a curved ceiling. Light transmission is better than in the gable type, but not as good as in the igloo.

However, the straight sides of the raised arch make the structure easier to work in than the igloo. Only flexible materials such as PVC film can be used to cover the curved roof-section.

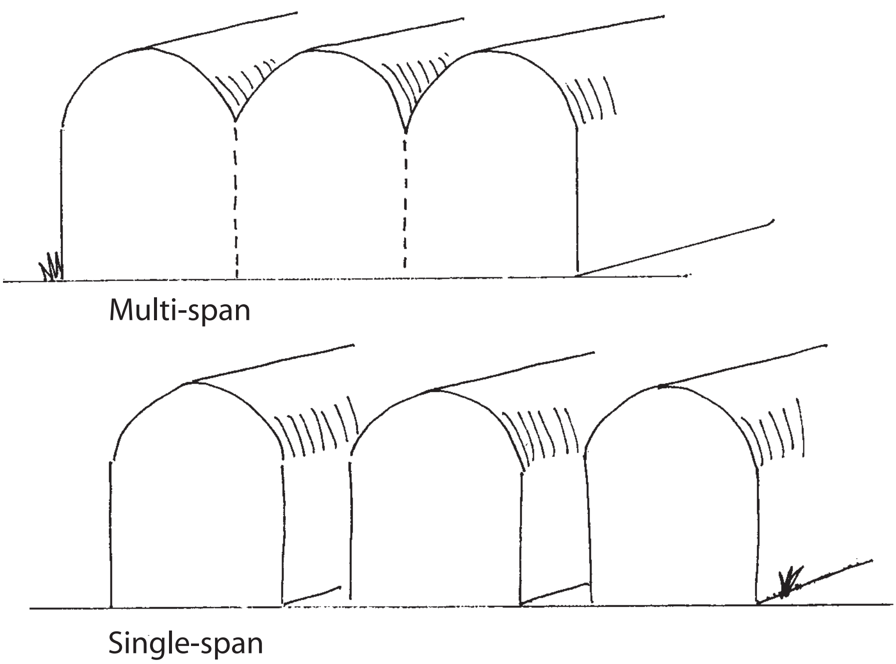

Figure 11.2: Different types of greenhouses.

Greenhouse designs for commercial nursery production

Venlo

Venlo is a common Dutch design, gable-style greenhouse, popular due to its ease of construction. Each side of the ridge roof is made up of a single row of large glass panes. The size of these panes limits the greenhouse to a narrow span of 3 m (10'). However, this problem can be overcome by erecting them in multiple spans.

Construction is based on a row of posts that support the gutters, with rafters attached directly to the gutters. The support posts impose limitations on the internal use; however, a new design using prefabricated roof trusses eliminates every second line of post supports. The gutters also allow access to the glass panels for cleaning or replacing. The end and side walls are usually covered with smaller panes of glass. The common method of roof ventilation is for every third or fifth pane to be raised.

Wide-span or multi-span

Used extensively worldwide where only one crop is grown, wide-span greenhouses are also preferred where the one stable environment is suitable for growing a diversity of plant species (as in a nursery producing plants for amenity horticulture). In Europe, blocks of greenhouses of this construction often cover up to 6 ha (15 acres). Because of the roof pattern, they are often called ridge-and-furrow greenhouse blocks. They can be extended when finance permits.

Advantages of this design are lower initial construction costs, and the capacity to manage a large crop in one house. The design allows for more efficient use of land and space, offers more varied use of internal space, and reduces heating costs. On the other hand, ventilation is more difficult as you rely on natural means, and installation of forced cooling systems will be needed in many situations. Large wide-span (up to 26 m/85' wide) greenhouses are costly to construct and heat; therefore they are not as popular as span widths of 4–10 m (13–33'). A multi-span structure is recommended if you want to build a structure more than 10 m wide.

Mansard

The mansard design refers to the roof design, which has two slopes on each of its four sides. The lower slope is steeper than the upper slope, which is not visible from the ground. This is a popular greenhouse design as it maximises space and light penetration high in the greenhouse, and this space can be utilised for hanging baskets or larger trees.

Plastic-clad tunnels or igloos

Curved-roof greenhouses are widely used throughout the horticulture industry. They provide uniformly high light transmission through the flexible plastic film (the most popular films are polyethylene, polyester and polyvinyl). The tunnels are the least expensive type of greenhouse structure to build, and the economical advantages are not only the initial cost of the film but installation and whole-life costs. The plastic films are much cheaper to heat than glass or fibreglass coverings. The durability of plastic products has improved, and they can now withstand severe weather conditions and many years of ultraviolet light exposure.

Although some growers construct their tunnels using galvanised waterpipes as frames, extruded aluminium fixing systems are also available. Double-skin air-inflated covers can reduce the heating costs by 40%. Ventilation has proved to be a problem with this type of structure. However, in recent years roof-mounted ventilators (not suited for windy sites) and manually operated side-wall ventilators have become available, making this less of a problem.

Sawtooth

This multi-span configuration of the skillion greenhouse is increasing in popularity due to its low cost and ease of construction. Ventilation is provided by incorporating ventilators such as louvres, pivoted shutters or roll-up blinds at the top of each vertical wall. Large sawtooth-type constructions do present ventilation problems due to the difficulty of getting cold air from outside into the centre spans.

Single-span greenhouses

Most single-span greenhouses have a span width of 4–10 m (13–33'); widths in excess of this are not cost-effective. Multiple single-unit arrangements enable independent environmental control of each house. Single-structure spans also enable easier ventilation by natural means. However, this is a more costly option in both space and initial structure cost. To avoid mutual shading between houses, care needs to go into initial positioning.

Retractable-roof greenhouse
Greenhouses of this type are used where hardening-off is required, as they avoid the labour of moving plants to help them acclimatise to full sun conditions. These houses allow flexible growing conditions – some have two or three covers for plant protection against wind, low temperatures or high light.

Table 11.1: Comparison of multi-span and single-span greenhouses

Multi-span advantages	Multi-span disadvantages	Single-span advantages	Single-span disadvantages
Less covering material required	Harder to control heat than in single-span	Easier to control heating	Harder to heat
Easier to heat overall area	Easy for pests and diseases to spread	Easier to control pests	Less-efficient use of ground space
Most efficient use of ground space		Provide more specific growing conditions for different types of plants	More structural materials required

Greenhouses and shadehouses are now commonly available in kit form for the home gardener, and may be used as a starter greenhouse for backyard nursery growers or for housing displays in retail nurseries. On a full commercial scale, these structures can be readily obtained in a wide variety of sizes and styles, often in multiples of a basic unit (e.g. 6 × 4 m/20 × 13', 10 × 4 m/33 × 13'), or they can be made to order.

Greenhouse construction methods and materials

- Shortwall – the transparent material covers the roof and only part of the sides. The lower parts of the walls are covered with non-transparent material such as timber or brick.
- Longwall – the transparent material covers all of the walls and roof.
- Tunnel – the framework is made from half-circle metal hoops arranged in a row to form a tunnel shape. Transparent material such as PVC film is laid over this framework.
- Lean-to – a structure is attached to the side of another building, such as a house, which hence forms one side wall of the greenhouse.

Framing materials
Metal. Aluminium frames are popular because they resist rust, and are relatively strong and lightweight. Galvanised iron or steel are also used, though over time corrosion can become a problem. Glass goes well with metal framing, but PVC film and other plastics can deteriorate if in direct contact with metal (as metal gets very hot in summer, sections of PVC film touching metal will crack or tear much sooner than parts not in contact). The strength of the various metals allows the use of structural members with smaller cross-sections than timber used for the same task. This results in reduced shading effects.

Metal frames are readily obtained in pre-formed shapes that can make assembly very easy.

Timber. Timber does not heat up like metal but it may rot, particularly in the humid environment of a greenhouse. Some treated timbers will last for many years. However, it is important to check that the materials used in treating the wood are non-toxic to plants. Also, pests such as mealybug may breed in timber. Timber is very readily worked with (it is easy to cut, nail and drill), and is very useful for constructing non-standard size greenhouses.

Covering materials

When choosing covering materials for a growing structure it is important to consider:

- insulation – the material's ability to retain heat;
- light transmission – how much of the light reaching the greenhouse will travel through the covering. Some materials become increasingly opaque over time, reducing the amount of light being transmitted;
- cost – some materials are initially more expensive to buy;
- life-span – some materials have a shorter life-span and may need to be replaced;
- flexibility – more flexible materials are easier to build with;
- durability – how much wear and tear they can withstand.

Glass. Glass is very rigid and cannot be used on tunnel-type structures. It is one of the best materials for insulation, light transmission and durability (it will last 50–100 years), but the most expensive. It is generally more resistant to storms than most other materials, but can be dangerous and difficult to clean up if it is broken. It is more readily cleaned than most other covering materials (cleaning is normally required only for some of the longer-lasting materials). Despite its advantages, because of its cost glass is no longer the preferred material.

Coreflute/polyflute. This is a semi-rigid material, with two layers of plastic joined by an internal layer of corrugated ribbing. Insulation qualities are good and light transmission is good, but less than glass or PVC film. Cost is reasonably low given that the material will normally last at least ten years. It has good resistance to inclement weather, and will not shatter like glass. Small puncture holes can be readily patched. It comes in large sheets or rolls and is easy to work with. The large size of the sheeting also reduces heating loss. These materials are flexible enough to be used on tunnel and arch-type greenhouses. Algae can sometimes be a problem on and between the sheets, however, and it tends to collect dust.

Corrugated PVC sheet. A semi-rigid material of moderate to high cost, average durability and good insulation. Light transmission is lower than most of the alternatives.

Polycarbonate. Long-lasting, very strong, expensive. Available in clear or smoky-grey sheets or corrugated. Excellent light transmission, flexible and easy to work with. It tends to collect dust.

Corrugated fibreglass sheet. Semi-rigid, similar to acrylic-coated PVC sheet but more expensive. Light transmission is not as good as with alternatives (glass, coreflute, PVC film), and it becomes yellow and brittle with age.

PVC film. A very flexible and inexpensive film, PVC film has a short life-span (normally of a few years) and is susceptible to damage from hail, winds and storms. There are many different types of films: some have reasonable insulation and good light transmission properties; others are poor in those qualities. Some have inhibitors to reduce the effect of UV light, which is the major contributor to the breakdown of most films. Condensation forming on the inside can result in dripping (on plants and you), and lead to heat loss.

In areas where weather damage is not a major problem, PVC film can be the most cost-efficient covering material. It is sometimes used as a double cover to improve insulation, but some light transmission is lost. The films can flap noisily in the wind, particularly if they have been poorly erected.

Reinforced PVC film. This PVC film has woven thread embedded in plastic to provide reinforcement, which improves its strength and durability. There is slightly less light transmission which at times can be an advantage, depending on the type of plants being grown. It is more expensive than standard PVC film.

Type of greenhouse appropriate for your nursery

When deciding which type of structure would best protect your plants, it is important to keep a few simple points in mind. These include:

- plant growth requirements – for example, whether you really need a glasshouse or whether a shadehouse will be adequate;
- space – the amount of space you have for the structure, or the amount required for the number of plants you wish to grow;
- cost – how much you are prepared to spend;
- product availability – whether it is easy to obtain and replacement materials are readily available;
- ease of construction – whether you have the necessary expertise to build such a structure, or whether you will have to pay someone else to build it for you. A kit form may be the best option;
- life-span – whether you will be at the same location for a long time or have plans to move in the near future, and how much effort you are prepared to spend on repairs and maintenance;
- local by-laws – whether there are any regulations governing use of such structures in your area, for example size limitations, type of construction, or siting restrictions.

Siting greenhouses

The following questions and information can help nursery managers decide where to put the greenhouse.

- Is the site on a slope or is it flat? Too steep a site will make it impossible to build the greenhouse unless the ground is terraced or levelled.
- Is the site in sun or shade? A windbreak will be useful, but take care to avoid shading the greenhouse.

- What sort of base will be used (concrete, gravel)?
- On what sort of soil will the greenhouse be built? A sandy soil will give good drainage from any watering, but a clay soil will not. You may need to install a drainage system before construction.

Orientation

A greenhouse that is sited with its ridge running east–west is best, as this will maximise the amount of sunlight received (and reduce shading). Your available space, however, might not make this practicable.

Greenhouse benching

Benches enable you to raise plants off the greenhouse floor, keeping them away from disease and often in better light. They also make work easier for staff (less bending). A tiered system of benches provides more useable space than the floor alone can provide.

Benches can be made from metal, wood or plastic. The surface should drain freely. Wooden benches should be treated with preservative to preventing rotting and infestation by pests such as ants or mealybugs. Capillary matting (a continually moist, absorbent material sold by some greenhouse companies) will help reduce the need for watering if it is used on a bench.

Greenhouse hygiene

The greenhouse can be isolated from the outside environment, which can reduce opportunities for pests and disease to enter. However, if pests and diseases do get inside, the warm and moist environment is conducive to their rapid spread. You should always start with a clean greenhouse. All paths and walkways must be free of weeds, soil and organic matter. Benches should be disinfected, and preferably made of metal. Containers should be sterilised and, along with growing media, should not be stored within the greenhouse.

- Good ventilation will provide some control.
- Sterilise the house annually, using disinfectants that are specifically suited (and labelled) for the purpose.
- Pasteurise beds in greenhouses annually, by steaming at 60–71°C/140–160°F for 30 minutes.

Problems with greenhouses

The following are the most common problems experienced with growing plants in greenhouses:

- overheating – on a hot day, the greenhouse temperature can rise very quickly and overheat plants before you realise. Ventilation and shading can keep the temperature down. In some locations a shadecloth covering may be required during summer months;
- frost damage – a severe frost will penetrate through the sides and roof of even the best greenhouse. If the house isn't heated, keep the most tender plants in the centre of the house away from the walls;

- plants drying out – the extra warmth in the greenhouse means that plants dry out faster and need watering more often.

Other structures for growing plants

Coldframes

Coldframes are in effect mini-greenhouses. They are most commonly used by home gardeners, but can also be effectively used in a nursery. The frame can be used to:

- grow seedlings;
- propagate cuttings;
- provide a protected environment for budding and grafting.

The frame is a simple structure, usually box-like with a hinged top. The walls can be of transparent material, such as polyflute, or of non-transparent material such as timber. The top is at an angle (so water can run off and the sun enters at nearly a right angle) and can be opened and closed for access and to allow air in, depending on the weather. Opening and closing the lid also controls the temperature and humidity.

The advantage of a coldframe over a glasshouse is that it allows greater coverage of ground space using fewer materials. Coldframes can be moved around to find the best spot, or changed from a sunny position to shade depending on the season. They can be designed so that new frames can be attached to existing frames.

The disadvantages are that you are working at ground level and not at a bench and, because of the smaller internal volume, the frame can heat up and cool down faster so it needs to be watched more closely. The angle of the top should be placed at a right angle to the sun, in an easterly or northerly direction; the back wall should face west or south.

Shadehouses

Nurseries use shadehouses as a staging area to ease plants into a harsher environment when they are taken from a greenhouse, or for regular growing of plants that may require growing conditions that are a bit more protected. They are used to protect plants from hot sun, wind or excessively bright light. A shadehouse can protect plants from extreme heat in the middle of the day or extreme cold in the middle of the night, while the plants adapt to the harsher outside conditions.

Shadehouses are also used to provide permanent growing areas for plants that prefer shade and will eventually be grown in shaded positions in a garden (impatiens, ferns, some orchids, azaleas, rainforest plants like gingers, monstera and philodendrons).

Shadehouses can be covered in materials such as wooden slats, woven or knitted shadecloth, or moulded plastic slats. These allow the passage of rainwater (reducing the impact of heavy rain) and air, but reduce the amount of light reaching the plants.

Knitted shadecloth is available in many colours (pale blue, sandstone, brown, white) as well as the traditional green and black. In terms of plant growth, green is the least desirable colour as the translucent green fibres make the light slightly green. Plants are least efficient at photosynthesising in the green wavelength of light. Also, the particular green used does not blend in with natural leaf colours. Black is perhaps the least noticeable colour. White shadecloth is good for growing plants – they are protected but still grow in bright conditions, as the light is reflected and dispersed as it passes through the cloth.

Knitted and woven shadecloth is available in different grades in terms of light transmission, (30%, 50% and 70% shade are common). The shade rating is determined at right angles to the light so, depending on the angle at which the sun hits the cloth, you will commonly get more shade than the stated amount. Some plants may not get enough light. The higher grades are used in hotter climates and to protect shade-loving plants, such as ferns, in summer. High-grade shadecloths are hail-resistant and have a life expectancy of 15–20 years. Shadecloth (50%) can also be used as a windbreak material.

Unlike the woven type, knitted shadecloth does not fray, making it easy to install using very simple fixing devices such as flat-headed roofing nails. The knitted cloth is designed to stretch over a frame and has greater elasticity than woven cloth.

Shadehouse designs

Gable/even-span. This greenhouse structure design can also be used for shadehouses. The pitch of the roof allows water to run off and hail to roll off rather than gather on top, as it does on flat-roofed houses. However, it is not used for commercial purposes due to the expense of construction.

Flat-roofed. Most widely used as a cheap and easily constructed commercial design. Framing materials are usually galvanised steel pipe with right-angled clamps to join the framework. However, this design tends to drip during heavy rains, and allow hail to accumulate.

Flat-arched. This shadehouse, although a bit more expensive than the flat-roofed type, is constructed with a slight dome in the roof that allows easy shedding of water and hail.

Tunnel or igloo. A versatile prefabricated house with a steel or PVC pipe frame that is used particularly in small nurseries, in widths of 4–10 m (13–33'). It usually has both a shadecloth and polythene film cover.

Environmental control in greenhouses

Plant needs

Every variety of plant has specific needs and tolerances for the environment in which it grows. Horticulturists talk about 'optimum conditions', 'tolerated conditions' and conditions which are 'not tolerated'.

Optimum conditions are the conditions in which the plant grows best. Some plants have a wide optimum range, perhaps growing equally well at any temperature from 18 to 28°C (64–82°F). Other plants have a narrow optimum range, such as growing well at temperatures from 24 to 26°C (75–79°F).

Tolerated conditions are the conditions under which the plant will survive but not necessarily grow; for example a plant might have an optimum temperature range of 20–26°C (68–79°F) and a tolerant range of –2 to 49°C (28–120°F). Not tolerated conditions are outside the tolerated range; under normal conditions the plant would die, or at least be damaged.

Note: These principles apply equally to light, moisture and other environmental conditions for a plant.

Environmental factors affecting plant growth

The key environmental factors influencing plant growth are:

- atmospheric temperature – the air;
- root zone temperature – the temperature of the soil or growing media in which the plant roots are growing;
- water temperature – temperature of the water used to irrigate the plants;
- light conditions – shaded, full light or dark;
- atmospheric gas – chemical components of the surrounding air. Plants give off oxygen but take in carbon dioxide during photosynthesis. Plants will take in some oxygen during respiration (converting stored foods such as glucose into energy) and release some carbon dioxide, but in an enclosed environment the amount of carbon dioxide in the atmosphere will soon diminish;
- air movement – movement of air through the space and around plants. Good air movement mixes gases and evens out temperature fluctuations;
- atmospheric moisture – the degree of humidity;
- root zone moisture – water levels in the soil or media.

Environmental controls

Nurseries manipulate the environment to create ideal conditions for the growth of plants. They use different types of equipment to control such growth factors as temperature, light intensity and duration, humidity and in some instances the levels of different gases in the air.

Natural light

Light is the source of energy for plants, and light energy combines with carbon dioxide and water to commence the process of photosynthesis. Therefore, it is important to ensure that maximum light intensity is provided in autumn–winter to achieve plant growth. The design of the structure and its orientation determine the light intensity.

Other factors include the frame of the structure. A timber frame must be painted white to reflect the light. The covering material must also be considered: glass transmits up to 89% of light, polyethylene 84% and fibreglass starts high but quickly diminishes as the material hazes from UV rays. Also, as the covering accumulates dust and grime, light intensity can be reduced by up to 20%. It is essential the glass be cleaned after the hottest part of summer.

Growing media

Media used in greenhouses do not usually contain soil, but are a soil-less mix containing equal parts peat moss or composted bark fines, vermiculite and washed river sand. The growing media must serve four basic functions: providing water; supplying nutrients; providing gas exchange to and from the roots; and providing support for the plant.

Nurseries prefer their growing media to have a high percentage of organic matter, which will not disappear during the life of the crop, a pH 5.5–6.0 for most crops, at least 15% by volume of air and a bulk density heavy enough to be able to support the plant.

Air temperature

Greenhouses require cooling during the summer months, as most locations experience summer temperatures that are detrimental to plants. Temperatures inside a greenhouse are often 11°C (20°F) higher than outside. Adverse effects from excessive heat include reduction of flower size, delays in flowering and loss of stem length.

Most plants prefer an air temperature of 15–24°C (59–75°F). You should maintain a constant day temperature 3–6°C (5–11°F) above the daily minimum and allow a 6°C (11°F) fall at night. To cool a greenhouse in summer you must bring large volumes of air into the greenhouse, to pass through the entire plant zone. Airconditioners are not recommended as the air is very dry and unsuitable, except for the production of mushrooms.

Moisture and misting

If intermittent sprays of water mist are applied to the top of cuttings, a temperature differential develops between the root and leaf zones. If the root zone can be kept warmer than the leaf zone, there is a tendency towards greater growth in the root zone. In other words, the warmest part of the plant will grow fastest. In addition, the increased humidity created by the misting reduces water loss from the cutting.

Misting systems generally have a solenoid valve between the water source and the misting system which remains open to ensure that cuttings never dry out. When electricity is applied the valve is closed and water is shut off. The solenoid valves are generally controlled by the following mechanisms.

Simple timers turn the system on to give a short pulse of water (e.g. 15 seconds) at regular intervals (e.g. 2–5 minutes). Intervals can vary according to season, local conditions, type of plants grown etc. This type of control is very dependable and can be used to control many individual systems simultaneously. Their major disadvantage is that they do not respond to fluctuations in local environmental conditions, such as temperature, humidity and light intensity.

A sensor, such as a pair of carbon electrodes set in an ebonite block (known as an electronic leaf or carbon block sensor) placed under the mist with the cuttings, is used to trigger misting. As the top of the block dries, the current between the sensors is broken. This causes a solenoid valve to open, releasing water into the misting system. The mist then settles on the sensor connecting the electric circuit, which in turn closes the solenoid valve, cutting off the water supply.

Another common sensor is the screen balance (or balance arm) control, which has a small, stainless steel screen on one end of a balance arm or level, to which is attached a mercury switch. When the mist is on, water lands on the screen, causing it to drop; this trips the mercury switch and turns off a solenoid, causing it to close. When water evaporates from the screen, it rises, causing the mercury switch to connect, which turns on the solenoid, and so releases water. The screen balance should be placed in a position where it will not be affected by wind. Salt deposits and algal growth can affect the balance of the screen, so regular cleaning must be done. This type of sensor is commonly used in areas where there are considerable fluctuations in conditions during the day.

Computer-controlled systems that monitor a wide range of environmental variables are increasingly being used to control misting. The mist droplet size should ideally be in the vicinity of 50–100 micrometres (0.002–0.004") diameter. The type of spray nozzle governs this (see 'Computerised environmental control', below).

Moisture and fog

Fog systems are a comparatively new development in nursery propagation. They are used as an alternative to the more traditional method of intermittent misting to provide cuttings with a humid environment, and many growers have gained extremely good results in striking cuttings.

The advantage of a fog system is that it creates the humid environment which is necessary to prevent the cuttings from drying out, but eliminates the water droplets that sit on the leaves in mist systems. Fog droplet sizes are less than 20 micrometres, and they remain airborne long enough for evaporation to occur so that the water is held suspended in the air as a vapour, unlike the larger drops from misting systems which fall out of suspension onto leaves etc. Humidity levels are 90–100%.

The absence of free water from the leaves results in reduced fungal problems, reduced leaching of leaf nutrients and improved aeration of the propagation media.

Cuttings propagated by the fog method have more successful strike rates, and are healthier and faster to develop roots. However, it is not an irrigation system, so extra watering may be required to prevent the media from drying out. Fogging systems are a lot more expensive than misting systems to set up, but are worthwhile for many nurseries due to improved strike rates, and reduced times to achieve a strike.

Figure 11.3: This fogging machine is being used to increase the greenhouse humidity, for humidity-loving plants.

Computerised environmental control

Computer-controlled equipment that manages a greenhouse environment is widely available. Such equipment can control temperature, humidity, light intensity, application of black shadecloth, light reduction, ventilation fans and irrigation. Computers can deliver a 15–25% saving in costs, and reduce labour considerably.

Computer-controlled environments can control the temperature to within 0.1°C, whereas manual control offers 2–3°C (2–5°F) control at best. They also do the job gently, which puts less load on the equipment than the abrupt changes resulting from manual operation. Computer controls work 24 hours a day, 7 days a week. They deliver the most cost-efficient control of heating/ventilating systems every minute of the day and night.

Intelligent environmental controllers

The most recent types of computer-controlled equipment are known as 'intelligent environmental controllers'. These systems are capable of sensing, adjusting and recording all aspects of the greenhouse environment, including temperature, light intensity, carbon dioxide concentrations and humidity.

Sensors are strategically placed within the greenhouse and linked to external computers which are programmed to activate an optimal balance of growing conditions. The measurements and adjustments maintain growth at the fullest potential, without unnecessary expenditure of energy. The adjustments are recorded so that the nursery manager can ensure growing conditions are maintained at optimum levels. The new computer control systems are manually programmed, which allows you to alter growing parameters to accommodate a new crop or incorporate new information.

Temperature control in a greenhouse

Heat must be supplied at the same rate at which it is lost in order to maintain the desired temperature. Heat is lost by conduction, infiltration and radiation. Loss by conduction occurs when heat is conducted through the covering material. In radiation heat loss, heat is radiated from the warm interior through the covering to colder objects outside. Heat is also lost through infiltration, where cooler air infiltrates the system from outside.

Any thermostats should be at the approximate height and positioning of the growing tip of plants, so that they best monitor the temperature there. They should be housed in light-reflecting boxes where they will not be abnormally affected by the cooling effect of watering, excessive heating or sunlight.

Methods of temperature control

Greenhouse temperatures can be controlled in several ways.

Sunlight

The sun will warm the greenhouse during the day. This effect varies according to the time of year, time of day and weather conditions. The way the greenhouse is built and the construction materials also influence the house's ability to catch heat from the sun, and hold that heat. For instance, heat requirements can be reduced by installing a second covering (e.g. PVC film) over the greenhouse.

Heaters

Heaters can be used to add to the heat in a greenhouse. The heater must be able to replace heat at the same rate at which it is lost to the outside, so that desired temperatures can be maintained. A central heating system is more efficient than localised heaters in maintaining temperature in a greenhouse. Localised heaters are cheap to purchase but more expensive to run. Emergency heaters (back-ups) are desirable (see 'Heating systems', below).

Circulated air

Air circulation facilitates the distribution of heat from source points (e.g. heaters), and is critical to ensure even temperature control. Air fans, to distribute hot air, are sometimes used. Large-diameter polythene tubes with outlet holes are also sometimes used. Vents and doors can be opened to let cool air into the greenhouse, or closed to stop warm air from escaping

Coverings

Shadecloth can be drawn over the house to reduce the amount of sunlight energy transmitted into the greenhouse. Greenhouse paints (whitewash) can be applied in spring with the same effect. The type of paint will normally last the summer, but wash off with weathering to allow penetration of warming light in winter.

Other methods include:

- coolers (blowers etc.) to lower temperature;
- watering or misting systems to lower temperature;
- exhaust fans to lower temperature;
- water storage, or rock beds, under the floor or benches of a greenhouse to buffer temperature fluctuations;
- hot beds to heat root zone areas and generally help heat the greenhouse;
- thermal blankets drawn across the top of greenhouses at night to trap heat gained during the day, usually by means of a small hand-operated winch.

Figure 11.4: Evaporative coolers are used to cool greenhouses and glasshouses.

Heat loss

An important consideration in temperature control is the heat lost through the walls and the roof of the house. Different types of materials (glass, plastic etc.) have differing levels of ability to retain heat. Heat is normally measured in BTUs (British Thermal Units). Table 11.2 shows the qualities of different materials.

Table 11.2: Heat loss with different materials

Covering material	Heat loss (BTU/sq ft/hr)
Glass (5 mm/0.25")	1.13
Double-layer glass	0.65
Fibreglass-reinforced plastic	1.0
Acrylic sheet (3 mm)	1.0
Polythene film	1.15
Double-layer polythene film	0.70
Polyester film	1.05

Source: Nelson, *Greenhouse Operation*, 1991.

Heating systems

The two main types of heating systems are localised heating and centralised heating systems.

Localised heating systems

These use several individual heaters that blow hot air into the greenhouse. Hot air is often distributed through a plastic tube (or sleeve), 300–600 mm (12–24") diameter which is hung from the roof and has holes cut at calculated intervals for distribution of warm air. There are several types of localised heaters.

Unit heaters, which have a three-step method of operation.

1. Fuel is burnt in the firebox to provide heat at the bottom of the unit (the fuel could be gas, oil or something else).
2. Heat rises through a set of thin-walled metal tubes or pipes, which heat up.
3. Behind the heated tubes is a fan which blows cold air through the pipes out the other side into the house.

Convection heaters are cheap to purchase and are frequently used by hobbyists and small commercial growers. They differ from unit heaters in that they do not have a built-in heat exchanger. Fuel of almost any type can be combusted in the firebox . Hot fumes then pass out of an exhaust pipe which can be placed between rows of plants, above the heater, or wherever you wish. The exhaust pipe should be long enough (or outlets placed far enough away from plants) that dangerously hot air does not come in contact with the plants. A metal stovepipe or insulated ducting is ideal; however, polythene tubing can be used as well. A potbelly stove or similar can be used as a convection heater.

Electric heaters can be used in areas where electricity is cheap. These generally consist of a heating element and a fan which blows air across the heating element and into the greenhouse.

Radiant heaters are low-energy, infrared radiant heaters which have become popular in the US. Growers report significant savings on fuel costs.

Solar heaters include several different types which can be used or adapted for use in greenhouse heating. The components of a solar heater are:

- the collector – these are usually panels heated by direct sunlight. The front is transparent to allow light to enter; the back is black and insulated to stop energy escaping. Light is converted to heat when it is absorbed by the dark surface;
- the heat store – water and rocks are two of the most common stores. Water can be passed through the collector and returned to a storage tank of water. Air can pass through the collector and return to the storage tank of rocks;
- the heat exchanger – pipes or tubes can pass through the heat store and out through the greenhouse and back to complete the cycle. A heat-exchange fluid or perhaps air can flow through these pipes.

A backup heater may be needed in conjunction with a solar system.

Composting organic matter can provide heat, particularly from the composting of matter such as fresh animal manures or sawdust, which can be spread as a layer on a section of the greenhouse floor. As these materials compost they release a lot of heat. The heat release is irregular and generally only useful for a few months, but it may be a cheap option if a ready supply of such materials is available, particularly for small structures such as coldframes. It is important that plants not be placed directly on such materials (unless you are experienced with their use) as the temperatures generated can be quite high.

Soil- or bench-warming units are common in many greenhouses, to heat soil in beds, the flooring material or the benchtops. This places the heated zone close to the plants' root zone, thereby stimulating growth there. It is thus a very useful propagation aid. Such heating usually consists of piped hot water or electric resistance wire which heats up when an electric current passes through it.

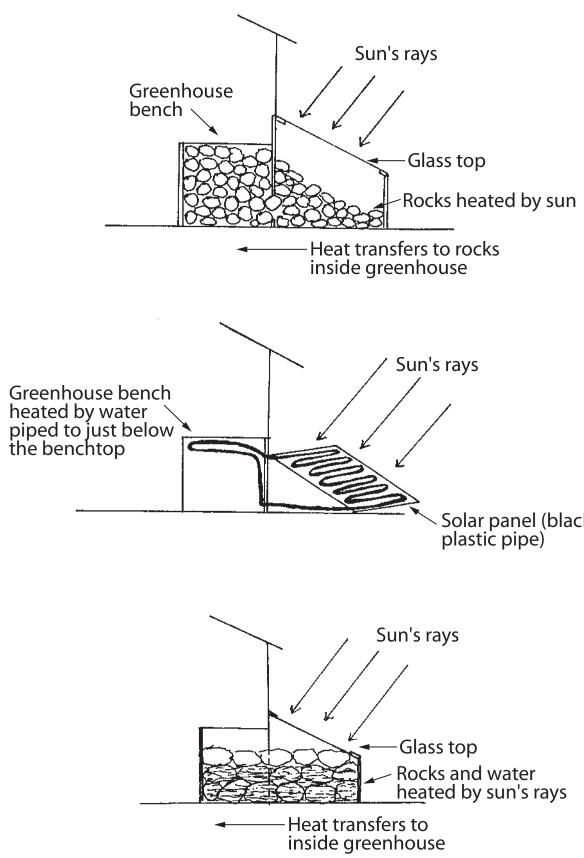

Figure 11.5: Methods of solar heating.

Centralised heating system

Centralised heating is usually provided by one or more boilers in one location, generating steam or hot water which is piped to one or more greenhouse complexes. It is usually the most expensive system to install and may be more expensive to operate. There are side benefits though; for example, the steam which is generated can be used to sterilise soil, pots etc. This type of system is only appropriate in large nurseries.

Ventilation systems

Use of vents and fans to control temperature and the balance of gases in the greenhouse environment is a very important aspect of greenhouse management. Ventilation is essential, to remove used air and maintain air circulation, which reduces the likelihood of a fungal disease outbreak.

Cooling equipment ranges from manually operated vents and shadecloth coverings in simple set-ups, to fully-automated cooling fans and ventilators in large commercial ventures. In very large houses, the use of forced-air fans is necessary. Cool air is introduced by evaporative cooling, where fresh air is cooled and pumped into the greenhouse and hot air is sucked to one end and dispelled. Air passed through fans can be heated or cooled for additional temperature control. By connecting fans to an electronic thermostat, it is possible to have them switch on and off automatically as and when ventilation is needed for temperature control.

Placement of the pad and fans of the evaporative cooling system is important. The most versatile placement of the pad is inside the greenhouse wall, allowing ventilators in that wall to open and close according to weather conditions. Exhaust fans should be at least 5 m (16') away from the pad, to prevent warm moist air moving towards an intake pad. When greenhouse walls are less than 4.6 m (15') apart, fans in adjacent walls should be alternated so they do not expel air toward each other.

Plants inside a greenhouse should be kept as far away as possible from vents or fan outlets, as temperature variations can be more extreme in these positions.

Controlling light in the greenhouse

Light is essential for plant growth, vegetative growth, flowers and fruit. Provided the plant receives the correct amount and quality of light, it will continue to thrive. Light is essential for photosynthesis. The green colour of plants is the result of chlorophyll, the site of the photosynthetic process.

The light spectrum can be separated into its colours, all of which affect plants differently. For example, the blue spectrum is involved in phototropic responses (the bending of plants towards the light source), whereas green light has little effect on plant growth. The intensity of the light source is important, as is the duration. Some plants, known as 'short-day plants', flower when the days become shorter (and the night longer); others are known as 'long-day plants'. This is not the rule, though, as some plants, known as 'day-neutral plants', flower irrespective of light duration. The red/far-red phytochrome pigments of light control these flowering responses.

Greenhouse structures frequently use lighting to assist growth by supplementing natural light. Plants respond to the artificial lights, as all lamps radiate different qualities of the light spectrum.

Lighting control mechanisms

Lamps
The following kinds of lamps are usually used in nurseries:

- incandescent (tungsten filament) – these are generally not ideal in nurseries. Among other things, the quality of light is poor and they create excessive heat. They have a high proportion of red light and this can facilitate fast stalk growth and bloom at the expense of longevity;
- fluorescent (e.g. Gro-Lux fluorescent lamps) – fluorescent lamps have been useful in propagation areas and with young plants, but are not suitable for plants in the latter stages of production. They help plants to flower for longer;
- high-intensity discharge (e.g. high-pressure mercury or metal halide) – these are the best for plants in the latter stages of production, prior to selling. They promote stem thickness.

Thermal screens
Thermal screens can be used to control the amount of ultraviolet light entering the greenhouse. The screens have a dark-coloured sleeve that fits onto the roof panels. A good computer environmental control system will extend the thermal sheets any time during the day when the light exceeds the grower's preset level.

Blackout
Some species benefit from short periods of complete darkness or blackout. These blackout periods produce shorter, more compact plants that develop uniform flowering. The older the plant the more readily it will produce flowers. For example, the number of flowers and flower buds on begonias peak when day-length is reduced to 10 hours and periods of blackout are implemented.

Shading
Shading includes the use of rolldown blinds, either wooden or plastic slats. If the blinds are fitted on the outside the temperature inside is reduced, but this usually means that the ventilators cannot be opened. If the blinds are fitted on the inside the internal temperature is not reduced, but the light intensity is. Blinds can be automated to open and close on preset temperatures.

Another method of shading is double sheets suspended lengthways from the internal roof trusses. These mechanically controlled systems roll the double layers into very small diameter rolls that minimise the loss of light. The upper layer is a white polyester fabric that reduces light by 45%, while the lower polyethylene level permits 90% of the light to pass to the crop.

A less commonly used method is applying a shading paint or product called Lightening Crystals, which can be sprayed on the roof. However, as it is not removable its practical use is limited in many situations.

Paint-based shading compounds
Paint-based preparations are ideal for semi-permanent shading requirements. They are applied with a brush, roller or spraygun at various densities, according to shading requirements of the growing species. A number of preparations can be applied directly to the outside of the greenhouse in spring when light intensifies. Light-coloured acrylic-based paints have a long-lasting effect. A Belgian product, Parasoline, available in a number of countries, overcomes the problem of too much shading at times of low light. This product can change from a white light-reflecting layer during sunny conditions, to translucent in rainy conditions, allowing light penetration.

Day-length manipulation
The purpose of day-length manipulation is to control flower growth. Plants such as chrysanthemums are initially grown under short-night conditions so that they are a suitable size to support large flowers and tall stems, then grown under long-night conditions to induce flower growth and development.

Short-night treatment simply entails turning on the lights in the late afternoon, to extend the day into the evening, or turning them on during the night to break the dark period. After a period of short nights, when the plant is established, a period of long nights must be introduced to initiate flowering. During winter the nights may be long enough, but during summer it will be necessary to cover the plants in late afternoon and remove the cover in the morning. Timer-operated automatic equipment can perform this operation.

Irrigation and nutrition control

The application of water is the operation that accounts for the greatest loss in crop quality. While it may seem to be a simple operation, incorrect watering, either at the wrong time or with the wrong volume of water, causes irreparable damage to the quality of the crop.

Watering should be commenced before the plant displays symptoms of moisture stress. It takes experience to determine the most appropriate time to water. However, watering in commercial greenhouses is almost always computer-automated, with sensors in the root zone which activate the watering system as required. Watering is rarely from overhead sprinklers. Watering systems must be designed to suit the crop. Most are from a central pipe with smaller tubes to individual plants.

Nutritional fertilisation of greenhouse crops is completely different to fertilisation of field-grown crops. In greenhouses, plant growth is forced in suitable conditions, with minimal soil volume. Therefore, fertiliser applications are a high priority if growth is to be maximised. The standard practice is to dissolve high-analysis fertiliser, high in nitrogen and potassium, into concentrated solutions which are proportionately delivered by an injector pump into the water line. Automated irrigation systems then deliver the liquid solution to each plant.

However, not all of the twelve essential elements need to be delivered continually. Some of the elements can be mixed into the soil prior to planting. These elements include calcium, magnesium, phosphorus, sulfur, iron, manganese, zinc, copper, boron and molybdenum. The NPK for the continued supply through the irrigation system should be in the range of 20:2:20, but this depends somewhat upon the crop species.

Carbon dioxide enrichment

Carbon is an essential plant nutrient and is suppled to the plant in the form of atmospheric carbon dioxide. It is used during daylight hours in the process of photosynthesis. At times, particularly during winter when greenhouses may be closed to reduce heat loss, carbon dioxide levels may be deficient and plant growth considerably reduced.

To overcome this problem, carbon dioxide is added to the greenhouse atmosphere during daylight hours. The most common method of addition is through the burning of kerosene, LP gas or natural gas in special burners inside the greenhouse. Concentrations of 500–1500 ppm will help accelerate growth of most crops, although there will be different responses between varieties.

Alternatively, bottled carbon dioxide can be used. This is usually more expensive than using a combustion heater, but has the advantage of not producing heat, which is not always desired, and not producing other gases and/or smoky fumes which can be detrimental to plant growth or settle on covering materials and reduce light transmission. Fertilising and irrigating programs should be stepped up to match the increased growth rates.

Sheds and workrooms

Buildings for storage

Buildings used for storage should be well-constructed and suitably protect the goods being stored. The degree of protection depends on the type of goods being stored. For example, furniture, clothing and electrical tools may require greater protection than outdoor gardening machinery. The building should also provide suitable security against burglars, curious children and animals. Inexpensive storage sheds are available in kit form. Better-quality sheds may cost considerably more.

Metal sheds in kit form are usually the cheapest. Some have each side and roof section already joined, and only six or seven pieces to join together – assembly is very easy. Others are broken down into dozens of pieces of framework and panelling, making the assembly job a more tedious process (perhaps a day's work). Metal sheds may rust more readily in seaside areas. Galvanised sheeting is your best option. Metal sheds can be very hot in summer and very cold in winter.

Brick or timber sheds are better insulated and are usually longer-lasting, but can be expensive to build. Some timbers require more regular protective treatments (e.g. preservative paints) than do brick or metal sheds. Materials such as fibro-cement or hardi-plank are easy to work with and can be a relatively cost-effective way of building a shed. They are better insulated than metal sheets.

A lean-to can be built very easily and cheaply, against an existing wall or fence, though council permits may be required.

Alternatives for roofs and walls

Your choice of material for walls and roofing will make a lot of difference to the way you can use a structure, the amount of maintenance you will have to do, how long the structure will last, how it looks and how much it costs. Consider the following factors:

- insulation – some materials keep the cold and heat out, others don't;
- light penetration – if you're going to work or grow plants inside, you will need a certain level of light from the windows. Some sort of light-transmitting material such as shadecloth, fibreglass or PVC are preferable for at least part of the roof or wall;
- ventilation – air needs to move through the structure to keep it cool inside and to reduce humidity which can cause mould on walls and roofs, or diseases in plants;
- cost – cheaper materials may be adequate in the short term but normally have disadvantages in the long term, particularly with regard to maintenance requirements;
- strength and durability – both the type of material you use and the size (thickness) can affect the strength and life-span. Some timbers will last a lifetime without any treatment, while others need preservatives to protect them against rot. Some metals will corrode. PVC plastics which are UV-stabilised will last much longer than non-UV-stabilised PVC surfacing materials;
- attaching objects to the wall – timber walls are simple to attach shelving to, but metal walls may be more difficult and require either a pop rivet gun or welding equipment. Some walling materials (e.g. thin metal) may not have the strength to support heavy shelves; other materials are stronger. Wall posters will adhere better to some surfaces than to others.

Siting work buildings and storage sheds

Some factors that should be taken into account when siting work and storage buildings may seem obvious, but are too often neglected. A good site should meet the following requirements:

- sufficient drainage – this is very important, particularly in areas subject to heavy downpours;
- good access – this includes clear passage into and out of the building not only for staff and customers, but also for goods and machinery where required. Pathways and driveways should ideally be covered with a durable surfacing such as concrete, gravel or pavers to provide a solid non-slip surface;
- a solid base or foundation for the building – if earthworks have been done to prepare the site, make sure that ground beneath a new building has been well-consolidated to prevent later subsidence, and that suitable retaining walls (or alternatives) have been built to prevent erosion or collapse of sloped areas;
- suitable distance from trees that might cause later problems – these include trees with strong root systems that may cause lifting, or large trees that drop a lot of leaves or even branches.

12

Management

Introduction

Management is the process of completing tasks efficiently with and through other people. It is about control, and achieving better results by exercising control. Many aspects of nursery management have little to do with horticulture. Both wholesale and retail nurseries are often successfully managed by people with backgrounds in a variety of industries.

Managers must understand and appreciate their own role as the person who controls what happens, *not* the person who actually does the work. A manager who spends a lot of time potting-up, weeding plants or talking with customers may find that they spend too little time managing the nursery, resulting in loss of control. In a small nursery, however, where these jobs must be part of their routine, the manager must maintain a delicate balance between the various tasks.

Good management only occurs when the manager is well-informed; hence the first task for any manager is to get to know the organisation for which they are responsible.

Operational flowcharts

To better understand the procedures involved in nursery production it is helpful to produce an operational flowchart which outlines the various steps undertaken in each of the four stages of production (propagation, transplanting, growing-on and marketing). Flowcharts can assist in many facets of nursery management including production efficiency, quality control, budgets and production timelines. Flowcharts can also assist staff in routine management and maintenance procedures.

An example flowchart for one method of propagating a eucalypt grown from seed is presented below.

Operational flowchart for eucalypt seed propagation

Propagation stage

- Obtain seed.
- Mix propagating media.
- Sterilise propagating media (if applicable).
- Fill seed tray.
- Water tray.
- Sow seed.
- Cover seed.
- Water seed trays.
- Place trays in propagation area (e.g. greenhouse).
- Germination takes place.

Transplanting stage

- Mix growing media (soil mix) or purchase soil mix.
- Sterilise media.
- Bring seedlings and soil mix to potting area.
- Transplant seedlings into pots or tubes.
- Move potted plants to a protected or semi-protected position (e.g. shaded position) for growing-on.

Growing-on stage

- Mix and sterilise or buy potting soil.
- Bring soil and plants together in potting area.
- Pot-up into container in which plant will be sold.
- Allow growth to full size (apply fertiliser and water, prune etc. as needed).

Marketing stage

- Prepare and label for sale.
- Load into van.
- Call on retail nurseries canvassing sales.
- Unload plants as they sell.

This is only one method by which eucalypts might be produced and marketed by a nursery. Regardless of the method you follow, a flowchart of operations can be beneficial because it highlights the steps in each stage of production and facilitates the analysis of these steps.

Flowcharts for operational efficiency

By closely examining your procedures step by step you can critically evaluate your efficiencies. You can identify areas where your operation is effective, and areas where it can be streamlined.

For example, can you save time (or money) by doing anything differently from the way it is done now? Perhaps you can eliminate mixing of media by purchasing a media which is premixed, or perhaps potting-up can be eliminated by direct-seeding into the container in which the plant will be sold.

Utilising flowcharts to help assess operational efficiency allows you to focus on the areas that will show the greatest improvement. A flowchart can also be expanded to include a column that lists the hours taken for each task. This can be used to determine which tasks are the most time-consuming, how much each task is costing you in terms of labour costs, and specific labour requirements for each task. This can help you make the most efficient use of your labour force (e.g. when to hire casual staff, planning tasks so that you don't have a lot of work one week and very little the next, allocating the most suitable employee to each task).

Flowcharts for quality control

Flowcharts are also beneficial in the control of product quality. The flowchart helps you to identify all inputs, and evaluate all methods used in the production system. The more detailed the flowchart, the more detailed the quality control procedures that are possible.

Some large nurseries record very detailed specifications, for example the volume of nutrients supplied in fertilisers or the intensity of light received by plants. Flowcharts assist in monitoring these factors as well as identifying the source of and rectifying any problems. Utilising flowcharts in this way involves not only listing the steps in production, but also itemising specifications of inputs and so on for each step. The flowchart format is useful for this because it allows specific quality control procedures to be implemented – and traced – to each step of production.

Human resource management

Recruitment

Finding and retaining good staff can be a problem for any nursery. Many nurseries never go looking for staff, relying instead upon people who come to them looking for work. Staff can be recruited via the following channels:

- universities and colleges – most horticultural courses require students to undertake several weeks of industry work placement, so nursery managers may be able to utilise such students as employees;
- advertising – poor advertising for positions can cause enormous problems. For example, advertising with employment services is unlikely to result in applications from skilled staff. Trade magazines, however, will reach qualified and experienced people. Weekend newspapers offer a much wider variety of people;
- professional associations – often such associations are aware of members who are between jobs or looking to move to a new job. They may also be willing to advertise employment opportunities in their newsletters.

Interviewing

In any organisation, the success of the worker depends upon:

- their skill in the assigned job;
- their ability to adjust to the organisation's hierarchy (fit into their place among superiors, subordinates and equals);
- their ability to adjust to variations, or lack of variations, in the work situation.

These particulars should be determined through an interview. Obviously the interviewer can only ask about hypothetical situations, and it is not possible to reproduce real emotional stresses which could occur in the workplace (although different types of stresses can occur in an interview).

Three rules should be followed when interviewing:

- keep the appointment time;
- avoid interruptions;
- make applicants feel at ease.

An interview is different from a conversation. The interviewer's task is to elicit sufficient information from the interviewee to make required rankings. To ensure information elicited is appropriate and fair, all interviews must be conducted in a uniform and unbiased manner. This requires a schedule and a degree of structure.

The interview schedule may consist of specific questions, and often a range of subsidiary questions which may be asked, depending on answers received for the main questions. The interviewee should be allowed to reply freely to questions.

The following are suggested questions for an interview:

- reactions to those in authority – how the person would react to their superiors;
- reactions to peers – how they would react to others working at their own level;
- reactions to subordinates – whether they would be capable of maintaining a correct boss/worker relationship;
- reactions to one's self – whether they would be able to maintain a decision they made. In other words, whether they would develop uncertainties and waver about decisions, or stand firm;
- reactions to work conditions – whether they would accept and follow written or established procedures, and whether the jobs or tasks are appropriate to their personality.

Interviewing can be time-consuming and costly. In large organisations, three interviews often take place:

- a preliminary meeting to weed out unqualified applicants;
- an employment office interview to select several candidates for the position;
- a final interview by the prospective supervisor.

In smaller nurseries, time can be saved by posting a job application form or questionnaire to applicants, then weeding out unsuitable respondents without the trouble of preliminary interviews. Remember, though, that the applicants are people in the industry and you should try to leave them with a positive impression of your business. Be courteous and encouraging in your replies, even when informing applicants they were unsuccessful.

Staff induction/orientation

Responsibilities for all employees should be clearly defined and in writing. A copy of their job description should be given to each employee when they commence work. It is important for a manager to read through the job description, point by point, with the employee to clarify and reinforce their understanding of what is expected. Managers should evaluate each person's responsibilities on a regular basis, and make adjustments where necessary. Ask the employee for feedback, and encourage them to make any suggestions they feel will make their work more efficient or enjoyable.

If managers change their expectations of an employee, they must inform the person concerned. The employee should be made aware that such adjustments to their job description can be made before they commence work.

Examples of nursery job descriptions and advertisements

Nursery manager: qualifications and experience required

Essential criteria

- At least 10 years experience in horticulture, with a minimum of 5 years in a production nursery.
- Experience in management, supported by positive references from previous employers or business associates.
- Success in operating their own business, preferably a nursery, even if small-scale or part-time.
- The ability to identify a large number of native and non-native trees and shrubs.
- A leadership style which is flexible but strong, providing firm decisions but at the same time seeking and incorporating input from workers.

Preferred criteria

- Experience in managing a successful nursery.
- Membership of professional or trade organisations such as the Australian Institute of Horticulture or the International Plant Propagators Society.
- Formal training in horticulture.
- Past attendance at conferences or seminars in the horticulture industry.
- Marketing experience.

Relationships

- Responsible to the directors of the nursery.
- In charge of all day-to-day on-site operations.
- Directions to workers to be given via section heads (foremen).

Duties

- Prepare work schedules (at least one week in advance, in consultation with the director) for daily work to be carried out in the nursery.
- At the beginning of each day, instruct each person what they should do that day, in accordance with prepared work schedules.
- If necessary, adjust what is planned on the work schedule.
- Observe what each person is doing on the site at least twice each day, and correct their work methods or techniques if necessary.
- In conjunction with the director, attend to record-keeping, purchasing (reordering stock, ordering materials), paying bills, promotion and marketing.
- Be responsible for ensuring adherence to legal requirements in operating the nursery (e.g. occupational safety regulations, employee awards).

Conditions

- Position will be reviewed after initial 12 months.
- Two weeks' notice to be given in writing to terminate employment.
- Hours 8 a.m. to 5 p.m., Monday to Friday.
- 4 weeks' annual leave, not to be taken before 11 months have passed.
- Sick leave etc. as are required by law.
- Salary negotiable according to experience and qualifications.

Number of positions

- 1 person for 1 year. Term may be extended.

Foreman propagator/tuber

Relationships

- Responsible to the nursery manager.
- In charge of all routine work in the potting shed.

Duties

- Sign the number of hours worked, in a daily record.
- Collect cutting material for propagation.
- Oversee the propagation and potting-up of plants, under direction from the manager.
- Be responsible for monitoring and ordering nursery supplies (pots, seed, fertiliser) with ample time prior to being needed.

Conditions

- Financial remuneration will be determined in accordance with the hours worked.

Number of positions

- Initially 2, full-time

Nursery hand

Relationships

- Takes instructions from the propagator or, when the propagator is absent, from the manager.

Duties

- Propagate plants.
- Pot-up plants.
- Weed, pest and disease control.
- Making up and processing orders.
- Developing and maintaining stock and display gardens.
- Other nursery work as required.
- Working in the garden.

Conditions

- Financial remuneration determined in accordance with hours worked, and subject to industry award conditions.

Number of positions

- Initially 1 full-time or 2 half-time positions; as production increases, the number of nursery hands would increase.

Administration/clerical officer

Relationships

- Responsible to the director and nursery manager.
- Responsible for all routine office/clerical work.

Duties

- Maintain filing systems.
- Take phone calls.
- Assist with handling correspondence, bookkeeping, record-keeping, taking orders and general assistance where required.
- Work with and ideally have experience with computerised office systems.

Conditions

- Position could be full- or part-time.

Number of positions

- Initially 1 full-time position.

Work scheduling

Nursery work can be divided into several different types of activities, such as office work, propagation, potting-up and plant maintenance. It is important to allocate adequate labour hours to each area each week. If there are several people working in a nursery, each can be given specific responsibilities. However, in smaller nurseries with one or two workers, roles are usually less defined.

Planning a work schedule should involve a number of steps:

- define objectives, goals and tasks to be achieved;
- put forward several alternative courses of action;
- analyse the alternatives and select the most appropriate course of action;
- decide upon the materials, equipment and supplies needed to complete the tasks;
- determine which staff are best suited to each task, and how many staff will be needed to realistically complete the tasks in a timely manner;
- put the chosen plan into action.

When developing a work schedule, consideration should be given to the following:

- interrelated work – many jobs are interrelated, so planning the time of a task should consider the effects on other tasks. For example, although extra plants can be propagated during wet weather, the extra stock could end up a waste of time and resources if the money and labour isn't available to maintain and pot-up plants later on;
- area of discretion – employees must know terms, policies and limitations set down by management. For example, if there are strict safety procedures to be followed, these must be accounted for when allocating time and resources to a certain job;
- routines – wherever possible, clear procedures should be developed for routine tasks. Different staff can then be allocated certain times to carry out such tasks;
- commitment – courses of action must be consistent with current and future commitments. Resources cannot be used if they have been allocated elsewhere;
- cost-benefit – generally speaking, if the benefit from each alternative being considered would be similar, the least costly course of action should be chosen. However, if one course returns a greater benefit than the others, then that is the preferred choice;
- credibility – the course of action selected must be acceptable to both your superiors and subordinates. If it lacks credibility it should be discarded;
- uncertainty – there should be minimum risk in the selected course of action. If it includes factors which you cannot be sure about, such as whether certain materials will be available on time, a different alternative should be selected.

Motivating employees

Figure 12.1: Staff are the greatest asset of any nursery. Well-managed staff will be productive and effective in their role.

Motivation can be defined as the employee's willingness to exert high levels of effort to reach organisational goals, helped by the ability to satisfy some individual need.

Motivating yourself and others is a key factor in success. We all have certain requirements which must be satisfied – being treated with respect, doing interesting work, receiving good working conditions and being rewarded with fair pay. These are all motivational factors.

Workplace incentives

There are other incentives, primarily within oneself, apart from those already stated. These incentives are mainly connected with the type of work the individual does. Factors that people find intrinsically rewarding act as motivators and produce job satisfaction These incentives include those listed here.

Pride in workmanship
Individuals find great satisfaction in a piece of work done well. This pride occurs not only in work which could be termed 'craftsmanship' but also in work of a routine nature.

The desire to see a task through
This is sometimes revealed in a statement such as 'I have finished that'. People take pride in the things they have accomplished.

Competition with oneself
Individuals sometimes set their own standards and rate of working. By doing this they are issuing a challenge to themselves and thus providing themselves with an incentive.

Subconscious satisfaction in having power
This occurs if the power is over people, even machinery.

Incentives also occur within the working environment. These incentives are external to the individual, but within the sphere of their work. These incentives are described below.

Part of the whole
An individual gains satisfaction by being part of the working team. This depends on managers keeping the workers in touch with the organisation as a whole and letting each individual know how they fit in.

Ambition for promotion
The possibility of promotion can affect incentive. Not everybody wants promotion, but

many do and if staff know that promotion possibilities exist then the incentive to work will increase. Of course, these promises of promotion must be real or they run the risk of backfiring.

Personal relationships
Some individuals prefer working near other individuals or groups and if management fails to set up these human relationships they will lose much willing work. Some workers prefer monotonous work because it gives them greater opportunities to converse with their colleagues.

Finance
The nineteenth-century industrial revolution believed that the financial incentive was the only important one when considering work. This has since been proven wrong. The financial incentive cannot be viewed in isolation; it must be considered along with other incentives such as working conditions, fringe benefits and medical aid. When considering financial incentives it is necessary to take the age, sex and temperament of the individual into consideration.

Training staff

Staff training is an ongoing and necessary aspect of any nursery. In some situations staff training is a legal necessity, such as when staff must be licensed to use certain dangerous chemicals. For example, in Australia, medium to large nurseries are required to spend a percentage of staff wages on training. In other situations training becomes necessary because new tools, equipment, materials, products or procedures are introduced into the workplace. Many nurseries deal with such changes by simply informing staff and assuming they will remember. This approach is rarely successful, and a more formal approach is necessary if changes are to be adopted and effectively practised.

Training employees makes good sense for many reasons.

- It reduces the time needed for new employees to reach acceptable levels of performance.
- It saves money, prevents misuse of equipment and avoids wastage of materials.

Figure 12.2: Ongoing staff training is an important consideration for a nursery manager.

- It provides employees an opportunity to gain new skills.
- It gives new employees security, which helps in the overall development of motivation.

Staff are the greatest asset of any business – even if you have the best retail site, the best store layout, the best range of products and the most competitive range of products, your business won't work if you have poorly presented, untrained and uncaring staff.

- Select the best staff and train them better than anyone else.
- Give them every reason to stay in your employment (and give them no reason to leave).
- Make sure your staff know very clearly what is expected of them.
- Remember always that questions from customers can lead to sales. If your staff cannot answer customer questions in an informative and friendly manner then customers are likely to go elsewhere.

Senior staff should set good examples when handling customers. Even if a customer wants to talk at an inconvenient moment it is important to make time to talk to them. If customers are not happy, sales will suffer. If senior staff handles customers well, juniors tend to follow their example.

Horticultural education

Properly educated nursery staff have the potential to be more efficient and productive. They are often considered to be the most important asset of a nursery.

There are two ways a nursery manager can access appropriately trained staff: employ people who are already competent, or employ people with potential and train them.

Nursery managers should consider the level of skills and training they require of their employees (and themselves). Any nursery, large or small, needs some staff with broad-based training and a way of thinking that will help the employees foresee future needs and take innovative action whenever needed.

How good are formal courses?

Some are very good, others are not. The quality of a course depends largely upon the people running it, and how well those people are resourced. Formal recognition is a minor concern in most nurseries. The things that matter most in this industry are the quantity and quality of plants, selling those plants and making a strong profit.

What about training in the workplace?

If you are unable to find qualified staff, it is possible to train them in the workplace. For example, you might consider the following:

- bringing in a trainer;
- training staff yourself – this can involve the use of training videos and resources or, if you have qualified staff, asking them to train other staff;
- sending staff to seminars, short courses and trade shows – these might be run by

educational institutions, industry accreditation organisations or local associations and societies;
- using distance education courses – for example, the Australian Correspondence Schools offers hundreds of horticultural and other courses, including many designed specifically for nursery workers. These range from courses for people who propagate plants at home as a small part-time business, to courses designed for managers or owners of large commercial operations.

How to learn

It is important for both trainers and managers to understand how learning happens. The process of learning is a complex field that requires years to master, but there are some aspects of learning that can be grasped and applied fast and easily.

Association

One of the best ways to remember something is through association. If you can categorise something, it will be easier to remember. If you can associate a particular plant with a plant family that you already know, you will more easily remember the name of that plant. When trying to remember something, first classify it into a category, then study the details pertaining to that thing.

Visualisation

Visualisation can greatly improve your capacity to remember. Try to imagine seeing things you are trying to learn. If you are learning about how people communicate, don't just read the words of a textbook, but imagine two people communicating using techniques described in that book.

Focus

Focus is important to any style of learning. The way to focus is to think about a general topic, then examine the various thoughts that are floating around in your mind regarding that topic, then systematically eliminate all but one thought – that one should be the most important one.

During the process you must remove or learn to ignore distractions such as noise, excessive cold or heat, hunger, interesting views through a window and so on.

Styles of supervision

Different supervisors will lead different ways, often influenced by their personality. Some people need to work hard to be a good supervisor because the style that best suits their workplace might be different from their natural tendencies. Here are just a few of the different styles of supervision:

- autocratic/domineering – these people are the boss, and they expect things done their way, or else! This style has serious flaws and rarely makes for a happy and cooperative group of employees;
- laissez-faire – these supervisors just roll along, letting things happen rather than making them happen. They may do a reasonable job but they are not usually high achievers;

- democratic – this is a cooperative approach where the supervisor makes the ultimate decision and takes ultimate responsibility, but constantly seeks the opinions of other staff and lets their opinions strongly influence decisions. This works, but poor decisions may be made if less-informed staff have too much influence;
- autocratic but humanistic – the supervisor makes the decisions, but welcomes suggestions. The staff do not influence decisions, but their ideas are sought and always considered.

Safety and illness at work

Accidents do happen, but risk can be lessened by making sure that:

- the job being done and all surrounds are safe;
- you educate your employees to carry out safe work practices;
- safety rules are understood and enforced.

Accidents occur in four major situations:

- wherever materials are handled;
- around machines (every type, even computers);
- wherever people walk;
- wherever hand tools are used.

A supervisor should stress safety at all times, because accidents are their problem – people are injured, production is reduced, machinery is damaged etc.

The significance of illness

Sickness or injuries can result in:

- monetary loss to the worker;
- suffering and stress for the worker and their family;
- loss of production;
- cost of repairs to equipment damaged by injuries;
- loss of material spoilt in injury;
- cost in money and time to train replacement staff;
- in the case of repeated accidents during a particular task, other employees may be unwilling to do that job;
- accidents which result in damage or injury to non-company people or property can result in bad publicity and high compensation payments;
- employees who are not in peak health don't work effectively;
- employees who are stressed or who suffer from tension or nervous disorders can be less productive themselves, and cause tension and stress among their colleagues.

Managing facilities

Organising the workplace

Every manager has to organise their workplace, whether one department or the entire business. A nursery may be reorganised because of change or expansion of the premises, or to improve efficiency. We organise to develop good work habits. When organising, the supervisor must:

- take a realistic look at the future;
- try to accurately forecast problems;
- determine alternative strategies to these problems;
- evaluate available resources.

Whenever reorganising anything, for example the work area, office furniture, workshop, stores etc., the following should be considered:

- who and what might be affected by reorganising – staff may resent changes if they are not consulted or reassured;
- writing down a list of the operations within the section being reorganised (e.g. potting-up, propagation, order-taking);
- what physical movement of people, equipment or materials is involved – find the most convenient and money-saving way of doing this without disrupting work. It may be necessary to do the reorganising on the weekend or after hours;
- whether delays to work are likely – if something is stopped or delayed this will be costly, so choose the most effective time to do the reorganising;
- whether anything will need to be stored and if so where – for example, records which are not current, equipment no longer or temporarily not needed;
- inspecting everything before and after reorganising – if items are being moved some distance, an inspection checklist can help ensure things are not lost between locations;
- analysing the reorganisation afterwards – whether the reorganising has been successful, whether it has saved time and money.

Productivity

A nursery can be thought of as a system where there are inputs (e.g. soil, labour and money) and outputs (e.g. plants and profit). Productivity is the relationship between the inputs and outputs. A nursery is considered more productive when maximum outputs can be achieved with minimum inputs, meaning that you don’t need to put any more money or effort into the nursery in order to reap the greatest benefit.

Productivity is most commonly measured in dollar terms as a productivity ratio:

- total productivity = total output divided by total input;
- total productivity = number of dollars received from plant sales divided by number of dollars it cost to produce the plants sold.

An indication of productivity levels can be deduced by monitoring specific aspects of daily work, such as:

- the number of cuttings taken per day, or the number of plants potted per day, by each employee;
- the total value sales achieved by each salesperson;
- the percentage strike rate on cuttings taken.

Some nurseries keep records of performance factors such as these and encourage more effort by giving a bonus or other benefit to the best-performing employee each week or month, or to any worker who achieves a set target (e.g. number of cuttings done per hour averaged over a month).

Costs should be continually monitored for changes which might affect overall productivity. Simple things such as changes in the personal life of an employee, increased charges from suppliers, deterioration of equipment or a change in taxation can have a significant but initially unnoticed effect on productivity. Such changes must be detected and countered quickly, whether by increasing prices or some other management decision.

Managing money

Calculating costs

The nursery manager must always have firm control over what it costs to operate the business. The costs involved in operating a nursery can be broken down.

Land

If this is owned, it still cost something to buy and it could have been leased out (and return an income) if it weren't being used for your nursery. A cost should always be included for provision of land.

Labour

Labour costs money. Even if it is you and your family doing the work, you are forgoing the opportunity of earning money elsewhere. Every single hour of work put into a nursery should be accounted for, otherwise, you will have no real understanding of your profitability/efficiency.

Work efficiencies are extremely important. For example, you should consider how many pots can be potted in one hour or how many cuttings can be done in a day. These types of figures can vary by factors of 100% or more from nursery to nursery. It is important to work out realistic standards which you and your workers can achieve, then closely monitor those standards.

Capital

If your capital is invested in a nursery, you are forgoing interest which the capital would attract if invested elsewhere. Any capital borrowed must be paid back with interest. Interest payments must be included in any costings. Borrowers should keep the following in mind:

- the loan should be for things which will improve the profit-making or efficiency of operation;
- do not borrow to simply build better working conditions such as a lunchroom or staff carpark – these should only be developed out of profits which have already been earned;
- make sure that you can meet interest and capital repayments and still maintain a reasonable level of liquidity;
- pay back the loan over no more, and preferably less, than the period for which your newly purchased asset will operate.

Equipment

A nursery can operate with basic equipment such as a spray unit, hoses and movable sprinklers, a few pairs of secateurs, a work bench, wheelbarrow etc. On the other hand, purchase of more sophisticated equipment such as potting machinery, computers or automatic irrigation might improve overall profitability and be very worthwhile by increasing the rate of growth of plants, increasing the quality of your product and decreasing the cost of labour etc.

The scale of operation will affect the profitability of adding sophisticated equipment to an operation; for example, a small nursery might be wasting money if it buys an expensive potting machine which is used only occasionally. Buildings, heating equipment and delivery vehicles should all be considered.

Materials

Soil, fertiliser, growth hormones, plant labels, pots and so on are all needed in operating a nursery. You can use cheap products of lesser quality, or expensive products of better quality. Your selection of materials will affect the quality and saleability of the plants you produce, as well as the cost of production.

PRACTICAL EXERCISE

1. Consider the formula: Cost of production + profit = sales price.
2. Plan the establishment of a new hypothetical wholesale nursery which is to produce trees and shrubs in 125 mm (5") plastic pots.
3. Set a sales price for plants to be produced. Be realistic. For ideas, look at the purchase price of such pots in local nurseries.

Sales price = …

4. Set a profit figure for the formula (probably 20–30% of sales price, depending on the scale of production).

Profit = …

5. Calculate what your cost of production should be.

Cost of production (per plant) = …

On the basis of this production cost, prepare a budget for your new nursery's first year of operation. Fill in costs below.

Budget

Number of plants to be produced in the first year: …
Number of plants to be thrown away (because they die, become diseased, get too woody etc. …
Number of plants sold in first year: …
Money generated through sales (income): …

Cost of production

Property and services	$…
Materials	$…
Pots	$…
Soil	$…
Fertiliser	$…
Other chemicals	$…
Stationery	$…
Labour	$…
Advertising/promotion	$…
Selling	$…
Other	$…
Total operating costs	$…

Now, consider how efficient your planned operation is. What things could you look at to increase your profitability? What costs might possibly be reduced? By thinking through these things you will hopefully develop an insight into efficient nursery management.

Example of estimating the cost of cutting production

Cuttings grown 200 to a tray with bottom heat and mist:

1 Materials used:
- plastic tray;
- propagating mix;
- label;
- rooting hormone;
- cutting material (if stock plants or cuttings needed to be purchased);
- other chemicals (e.g. drench for control of disease).

2 Labour:
- collecting and preparing cuttings;
- filling trays;
- inserting cuttings;
- chemical drenching tray;
- placing in propagating area.

3 Operating costs:
- energy cost for running propagating area;
- cost for total area, divided by number of trays in that area.

The total cost of producing a tray should be multiplied by the % strike rate and divided by the number of cuttings to obtain the cost of producing each rooted cutting.

Cash flow

The availability of cash varies considerably throughout the year. If plants are mainly sold in spring, then cash will be available in late spring and summer from payments for those sales. However, during winter when sales are reduced you might be spending a lot on wages but taking in very little cash. You need to plan ahead for when cash is going to be short, and put aside money in the good times to carry your operation in the bad times. A cash flowchart can easily be produced by listing the months and writing when cash is going out and coming in (see Table 12.1).

Table 12.1: Cash flowchart

	Expenditure	Income
January	Seasonal labour	
February	Pots and soil	
March		Autumn sales
April	Casual labour	Autumn sales
May		
June		Low sales
July		
August		
September	Pots and soil	
October	Casual labour	Spring sales
November	Casual labour	High sales
December	Seasonal labour	High sales

Table 12.1 is only partially filled in, and of course your situation will be different, but the concept remains the same. Preparation of such a chart is valuable in ascertaining a broad picture of your cash flow throughout the year.

Financial statements

The two main financial statements are a balance sheet and a profit and loss statement. These give an overview of the financial situation of a nursery at a given time.

The monthly financial statements are usually the best records for seeing how well the nursery is going, as they show the cash flow situation. Early in a nursery's development it may be necessary to do cash flow statements weekly. Simple examples of these two types of statements are set out in Tables 12.2 and 12.3. Many nurseries prepare these and other financial statements and records using simple computerised accounting packages. For advice on which of these would suit your needs, consult your accountant or firms selling computer software.

Table 12.2: Balance sheet of GreenPlant Nursery as at 31 June 2004

Liabilities		Assets	
Current liabilities		**Current assets**	
Bank overdraft	$10 000	Cash and bank accounts	$2385
Accounts payable	$3560	Stock inventory	$29 565
Long-term liabilities		**Fixed assets**	
Debentures	$20 000	Equipment	$42 500
Mortgage	$25 000	Property	$155 000
Total liabilities	*$58 560*	*Total assets*	*$229 540*
Proprietorship			
Owner's capital	$170 891		
Total proprietorship	*$229 451*		

Table 12.3: Profit and loss statement for GreenPlant Nursery for the 12 months ending 31 June 2004

Revenue	
Net sales	$650 000
Expenses	
Materials	
Labour	
Depreciation	
Miscellaneous operating costs	$22 000
Add: Opening inventory	$30 165
Deduct: Closing inventory	$29 565
Equals: Cost to produce plants sold	$22 600
Gross profit	**$42 400**
Less marketing/administration costs	$6 400
Less taxes, rates, interest etc.	$9 300
Net profit	**$26 700**

Cash book

The cash book is simply a book into which you write all financial transactions. Money which is received is placed in the right-hand column under credit (Cr); money spent is placed in the left-hand column under debit (Dr).

Table 12.4: Example of cash book entries

Date	Item	Dr	Cr
24/5/04	Postage – general	$24.70	
24/5/04	Order – school		$158.00
24/5/04	Petrol – delivery van	$30.00	
24/5/04	Rent – for April	$855.00	
24/5/04	Cash sale		$395.00

Record-keeping

It is extremely important to keep accurate records of spending, the moneys coming in and the plants in stock (and their current value). These details are important not only to financial management, but also to marketing and general management.

Accurate records must be kept on every aspect of a nursery's operation. These are often necessary for taxation purposes, but are also an invaluable management tool for control of daily operations and necessary analysis of trends for planning future operations.

Managing stock

Stock control is an important part of managing any nursery. Records of current stock are important to assist in designing a marketing program and to know how much capital is tied up in stock.

Propagation records

Propagation records provide a valuable source of information for a variety of reasons, including those below:

- long-term records allow growers to compare the effectiveness of a range of seed and cutting treatments, enabling them to determine factors such as the most effective concentration and type of hormone for each species;
- they also allow growers to determine whether factors such as the type of cutting, source of propagation material, time of year or placement in the nursery have any effect on strike/germination rates;
- by recording the propagator's identity, managers can identify the existence of any deficiencies of skill or commitment. This information is not only economically valuable in terms of increasing productivity, but can also be used to enhance staff training programs.

What to record

Records can be kept on computer, a simple card file system, or in a record book or ledger-style arrangement. The first step is to keep a daily record of production, including the type of plants propagated, how many were propagated, the propagation method, the date and names of the propagators. Table 12.5 is an example of how to draw up a daily record form.

Table 12.5: Daily propagation record sheet

Plant name	Quantity	Propagation method	Propagator	Date

The next step is to produce a record for each crop. An example of what to record is shown in Table 12.6.

Table 12.6: Example of a crop record sheet

Botanical name______________________________

Common name______________________________

Date: Propagated/sown_______________Rooted/breaking_______________

Method_______________Size (for cuttings)_______________

Propagation medium______________________________

Bottom heat______________________________

Treatments______________________________

No. or grams of seed/cuttings per tray______________________________

Area to be placed______________________________

Date/s potted-up_______________No./s potted up_______________

Source of prop. material_______________Date obtained_______________

Propagator/s______________________________

Results e.g. % rooted______________________________

Comments (e.g. attacked by insects)______________________________

The results from these cards can be consolidated into a single set of records for analysis.

Computers in the nursery

This section has been adapted from information contributed by David Mason, computer consultant.

Since the early 1980s, personal computers have been used by small businesses and increasingly in nurseries, to make life easier. They take the repetitiveness out of searching through files for a company's phone number and speed the calculation of numbers in a spreadsheet. They allow a company to create newsletters, signs or banners, to control payroll runs and to do bookkeeping.

Apart from general office tasks such as these, computers have a host of additional uses in a nursery, ranging from controlling aspects of the environment in which plants grow (e.g. switching on and off heaters, coolers, irrigation etc.), barcoding of plant stock to aid stock control, and as an information database to advise on technical problems as they arise.

Software and hardware

Hardware is a term used to refer to the machinery which makes up a computer system. It is the tangible parts of a computer – the things which you see and touch such as the screen, keyboard, case and electronic circuits.

Software is the intangible part of a computer – the programs or, if you like, the instructions which people have put into and stored in the computer. A computer is useless without software. Software allows you to interact with a computer.

Choose your computer software carefully, looking for software that has a well-established name. Look in computer magazines, or ask a computer dealer about common software packages.

Types of software

- System software – this is the operating system for your computer, like the desk you do your work on. There are many different types of operating systems, each with advantages and disadvantages.
- Utility software – these are software 'tools' that help manage, repair and maintain a computer or computer network. These may be programs such as hard disk repairers, file backup programs or undelete utilities.
- Application software – this is the software the user mostly operates. It consists of programs such as wordprocessors, databases, spreadsheets, games, desktop publishers etc.

Computer applications

Word-processing

Word-processing is much the same as typewriting, except that the writer can see what is written and change it before printing a paper copy. Also, the writing can be 'saved' or stored away on the computer, then recalled (altered if need be) and printed again, whenever required. Word-processing programs allow a nursery to write, store and print information sheets for customers as required, or a wholesaler to develop and print catalogues and price lists. Good word-processing software can be used for myriad functions from writing business letters to printing posters or advertising brochures.

Spreadsheets

Spreadsheets are an excellent way of keeping track of expenses, budgets and statistics. A spreadsheet is a large form (or a whole set of forms) comprising cells that each contain some data. You can make these cells relate to each other by using formulas. For example, you might have a spreadsheet set out as shown in Table 12.7.

Table 12.7: Example of a spreadsheet

	1	2	3	4
A		Plant 1	Plant 2	Plant 3
B	January	$100	$ 50	$100
C	February	$110	$1000	$100
D	March	$90	$90	$200
E	April	$200	$70	$100
F	May	$500	$500	$50
G	June	$700	$ 20	$900
H				
I	Total			

The cells are named by their coordinates on the spreadsheet (e.g. January is in cell B1 and Plant 2 is in cell A3). If you wanted a formula to add all the values for one plant and place the value next to Total, you would move to cell I2 and type ‘ =sum(B2:G2)’. This tells the computer to add all the values from B2 to G2. It also means that if any values are changed for Plant 1, the change will be reflected in the Total. This is because values are constantly looked at by formulas in a spreadsheet. Another advantage with spreadsheets is the ability to embed or put data-related graphs into the sheet, which can be kept up-to-date the same way as formulas.

Databases

Databases are like three-dimensional vehicles for information storage, an electronic equivalent of a card file system. Databases allow you to keep and print mailing lists, keep records of suppliers and customers and keep track of stock. The database user can ask for only certain types of information to be displayed. For example, a database might contain information on every plant species in a nursery, how many plants of each species are in stock and the watering and fertiliser requirements of each species. From such a database, you can extract very specific information such as which species of plant need to be fertilised with slow-release fertiliser every Thursday.

Environmental control

The environment around plants can be controlled with computers. There are three parts to such a system:

- sensors – these sense changes in the environment such as a drop in temperature, dryness in the air or soil, lack of ventilation, lack of light or an inbalance in the gases in the air;
- environmental control equipment – these are things used to correct environmental changes such as heaters, cooling machines, automatic vents, artificial lights, gas injection equipment etc.;
- computers – these link the sensors to the environmental control equipment, and activate or deactivate the environmental control equipment when the sensors tell the computer that a predetermined set of conditions has occurred.

These systems may be relatively simple or extremely complex, dealing with only one aspect of the environment, such as water, or many different factors.

Barcodes for nursery products

This section has been adapted from information contributed by Brian Collins, D4 Data.

Barcodes are a small block comprising lines of varying width and distances apart. The arrangement of each group of lines (each barcode) being used in any establishment can be made different from all others. Sensors can be used to distinguish between different barcodes and match them to different batches of information, which are then put into a computer. The user can alter this information as and when necessary.

The barcoding system common in shops has applications in retail nurseries. These systems reduce the amount of time needed to process plant information such as plant prices. With long queues at registers in peak seasons, such as early spring, the availability of barcoded plants can help speed up customer service. Some nursery items such as chemicals and fertilisers arrive with a barcode already on the packaging, and barcodes can either be printed on plant labels or stuck to a plant pot. Alterations to prices are then as simple as changing the computer scanner memory or using a different label.

The benefits of barcode labels are not restricted to retailers. They can be used effectively by growers within their own operations. Barcode labels may be used in conjunction with hand-held data entry terminals to prepare invoices, collect and update production records and make stocktaking fast and accurate.

Business planning

The business plan is a guide to your business, which allows the reader to understand the culture, vision, goals and objectives of the new venture. It allows the entrepreneur to think through all aspects of organising and operating a small business and helps them to decide if the business will be viable or if new directions should be taken. It also provides a facility for examining the consequences of different strategies, and for determining the resources needed to launch or expand the business.

Without a business plan, the owner/manager will have only a general idea of where they are going, what they hope to achieve and how they intend to go about achieving it. Business plans must be flexible and revised frequently to allow for changes in the external environment.

The main benefits of developing a business plan are:

- it forces the small business owner to justify their plans and actions;
- it identifies the business's strengths and weaknesses;
- it helps test the viability of the business;
- it assists in maintaining the business operations, focusing attention on the goals and objectives;
- it indicates the small business owner's ability and level of commitment;
- it assists the business to be proactive rather than reactive.

Writing a business plan involves examining all the aspects of what will make your business viable, and lets you make any last-minute changes before you launch your new enterprise. Part of your business plan involves formatting all your budgets and projections into cash flowcharts and spreadsheets, which clearly show how and when you're going to make some money.

The planning process is a means of formalising your thoughts and ideas, in order to establish the framework and direction of your business. You need to know how you will achieve the goals and objectives you have set. You can do this by developing an action plan. This plan should be prioritised and clearly outline who will be responsible for carrying out each activity within the required time frame.

There are many ways of setting out a business plan. Some are very detailed, others are not so detailed. Some present a plan for only one year, others for many years. We live in an immediate world, and the most impressive business plans are those that are concise and easy to read, and written with the passion and energy of the entrepreneur behind the business.

The following example shows one way of setting out a business plan. This is a serious and viable plan but, given the uniqueness of every situation, it should be carefully adapted to any real-life circumstances before you follow it.

PRACTICAL EXERCISE

NURSERY DEVELOPMENT BUSINESS PLAN

Introduction

GreenPlant is a hypothetical business located about 100 km from the nearest capital city. The site has 2 ha available, with the option to expand. The nursery will be a relatively simple operation, producing tubestock limited to varieties easily grown from seed or cuttings. The principal markets for these plants are retail and wholesale growing-on nurseries. Other markets might include direct sales to the general public, farmers, parks departments, tourists and production for specialist retailers.

The aim is to produce at least 150 000 plants in the first year, increasing to 500 000 within three years. The nursery will initially require a work building, storage areas, a propagating structure (polyhouse), an additional two polyhouses for establishing newly transplanted seedlings and rooted cuttings, and a shade area for growing-on and hardening-off stock. The final desired plan for the 2 ha site is a wholesale propagation nursery with a retail area and a display garden, which will also act as a source of propagation material.

It is envisaged that a nursery will initially provide enough work to fully occupy 3–4 full-time workers, and several casual/part-time staff. The staff employed will be experienced personnel, plus trainees who will become a larger percentage of staff as time progresses.

Planning

- Develop a broad concept plan for developing the site. The design should include the garden and stock plant areas in addition to the nursery layout, and must allow for expansion and other future developments. It should be drawn up by a consultant skilled in both nursery operations and landscape design.
- Develop basic nursery facilities – employ qualified tradespeople or experienced contractors.
- Ensure there is sufficient propagating material available when required. Purchase or collect seed, and obtain stock plants while basic nursery facilities are being constructed. Propagation should commence as soon as the main nursery facilities are complete; with some collection and preparation of propagating

material having occurred prior to and during construction. The first month of operations (including at least 2 weeks of propagation activity) should be considered a training period. It is extremely important that a skilled, experienced and commercially successful nurseryperson manage this period of the operation. Propagators must also be experienced, to ensure high productivity and quality.

Plant selection

When deciding what plants to grow or stock, the following criteria must be considered:

- ease of propagation – varieties that are easy to propagate may bring a lower wholesale price, due to an oversupply in the market, and although the more difficult species are often more costly to produce due to high losses and/or long time in production they can fetch a much higher price;
- time – some species can be ready to sell in less than a month, while others may take much longer. In the initial stages of the nursery, it is extremely important to produce plants quickly, in order to generate cash flow and establish a market profile;
- suitability to your facilities – the facilities briefly described in the introduction should provide the basic requirements for the propagation of a large range of seed- and cutting-grown plants;
- suitability of climate – it is always more efficient to work with the environment than try to create different environments;
- demand for particular varieties – it is important to grow plants for which there is a market. The initial market research will provide some information on the types of plants to grow. Further plant varieties can be added, based on information included in the marketing section of this plan. This can be amended or updated according to market demands, the availability of stock, and as skill levels and facilities are improved/upgraded.

Production schedule and estimated gross returns

No matter what kind of venture you are starting, even a non-profit one, if it is not funded properly it will not be around very long. All economic aspects of your enterprise must be well thought-out and organised, with as much formal planning as possible. Startup costs must be calculated, and the source or sources of funding confirmed. Ongoing monthly costs must also be estimated, and methods of payment established.

The following production schedule provides for the progressive development of the GreenPlant Nursery to a production level of approximately 500 000 plants per annum after 3 years.

The following notes apply to the figures listed in the production schedule.

- A relatively unskilled propagator produces about 750 cuttings per day, or 14 000 a month.
- The number of cuttings taken is based on initially 1 propagator working on cuttings 5 days per week and 1 propagator/tuber working on both seeds and cuttings, both working an 8 hour day, 45 weeks per year. During spring and summer, further casual staff will be employed to take extra cuttings. By the end of the third year, 3 full-time propagators will be employed to produce the half-million plants required, extra greenhouse space will be available and, hopefully, there will be many loyal customers ready to purchase.
- The estimates for cutting strike rates (80%) and the survival of cuttings and seedlings after tubing (95%) are based on survival rates for similar nurseries in Victoria, Australia.
- Returns based on an average price of $1.10 per/plant (prices range from 75c to $1.80).

Table 12.8: Yearly production schedule by month

Month	Cuttings taken	Cuttings struck	Seeds germ.	Plants tubed	Ready for sale	Return ($)
			Year 1			
January	10 000	0	0	0	0	0
February	14 000	8 000	3 000	11 000	0	0
March	14 000	11 200	4 000	15 200	10 450	11 495
April	14 000	11 200	5 000	16 200	14 440	15 884
May	14 000	11 200	5 000	16 200	15 390	16 929
June	14 000	11 200	5 000	16 200	15 390	16 929
July	14 000	11 200	5 000	16 200	15 390	16 929
August	14 000	11 200	5 000	16 200	15 390	16 929
September	28 000	11 200	10 000	21 200	15 390	16 929
October	28 000	22 400	10 000	32 400	20 140	22 154
November	28 000	22 400	10 000	32 400	30 780	33 858
December	28 000	22 400	10 000	32 400	30 780	33 858
Totals	**220 000**	**153 600**	**72 000**	**225 600**	**18 3540**	**201 894**
			Year 2			
January	28 000	22 400	10 000	32 400	30 780	33 858
February	28 000	22 400	10 000	32 400	30 780	33 858
March	28 000	22 400	10 000	32 400	30 780	33 858
April	28 000	22 400	10 000	32 400	30 780	33 858
May	20 000	22 400	10 000	32 400	30 780	33 858
June	20 000	16 000	8 000	24 000	30 780	33 858
July	20 000	16 000	8 000	24 000	22 800	25 080
August	20 000	16 000	8 000	24 000	22 800	25 080
September	35 000	16 000	12 000	28 000	22 800	25 080
October	35 000	28 000	12 000	40 000	26 600	29 260
November	35 000	28 000	12 000	40 000	38 000	41 800
December	35 000	28 000	12 000	40 000	38 000	41 800
Totals	**332 000**	**260 000**	**122 000**	**382 000**	**355 680**	**391 248**

			Year 3			
January	36 000	29 750	12 000	41 750	39 662.5	43 628
February	36 000	30 600	12 000	42 600	39 662.5	43 628
March	36 000	30 600	12 000	42 600	40 470	44 517
April	36 000	30 600	12 000	42 600	40 470	44 517
May	28 000	30 600	12 000	42 600	40 470	44 517
June	28 000	23 800	10 000	33 800	40 470	44 517
July	28 000	23 800	10 000	33 800	32 110	35 321
August	28 000	23 800	10 000	33 800	32 110	35 321
September	52 000	23 800	20 000	43 800	32 110	35 321
October	52 000	44 200	20 000	64 200	41 610	45 771
November	52 000	44 200	20 000	64 200	60 990	67 089
December	52 000	44 200	20 000	64 200	60 990	67 089
Totals	**464 000**	**379 950**	**170 000**	**549 950**	**501 125**	**551 237**

Initial costs

There will be four major types of costs associated with the establishment and subsequent operation of the GreenPlant Nursery. These are:

- capital costs – the initial purchase of land and buildings, propagating structures, vehicles and trailers etc. Much of the capital costs required for the first 5 years of operations will occur in the first 6 months. These expenses are incorporated into operating costs in the profit and loss statement through the depreciation on the asset;
- operating costs – these include products or materials that will be used up in the production of plants, such as pots, chemicals and seed trays. These costs will expand in line with increased production levels – as more plants are grown then more potting mix and pots will be required. This section also includes other operational costs not directly related to plant production including insurance, rates, electricity and phone;
- labour costs – wages, holiday pay, workcare levies and superannuation;
- training costs – these include the costs of courses undertaken by staff; attendance at workshops, conferences and seminars, as well as reference books and manuals.

Propagating and growing-on structures

To provide sufficient propagating and growing-on areas to produce the quantity of plants listed in the production schedule (Table 12.8) the nursery will initially require 3 polyhouses, each comprising 60 sq m of floor space. Additional polyhouses covering 180 sq m will be required in the third year of production and a further 180 sq m in the fifth year. A shade area of approximately 150 sq m will initially be required, with a further 150 sq m required in the third and fifth years of production. Sufficient undercover work space with benches will be required for the preparation of cuttings and for tubing-up.

Nursery equipment and consumable materials

Consumable materials include chemicals, hormone preparations, fertilisers, growing media, trays, pots, tubes, labels and so on. An indication of the types, quantities and approximate costs of both non-consumable and consumable materials required to produce the target production is listed below. These figures also include requirements for specific items required for the operation of the community garden.

The equipment required for the nursery will include a range of propagating tools (knives, secateurs, dibbles etc.); material-handling equipment (trolleys, wheelbarrows, shovels etc.); and other items, such as backpack sprayers, protective clothing and other safety equipment. Growing media should be purchased in bulk from Melbourne, at least in the early stages. Despite the distance, Melbourne suppliers are the closest who can supply the quality needed to ensure best results. It would be too expensive and complicated to attempt to make mixes on-site in the early stages of the nursery.

Figure 12.3: One of the primary concerns of a nursery manager is staff safety. Staff must be trained in safety procedures and given the proper protective equipment.

Summary of major costs

Table 12.9 includes a list of facilities, equipment and services required for the establishment and operation of the GreenPlant Nursery, and the associated costs (excluding labour and training costs).

Table 12.9: Summary of major costs (excluding labour and training)

Capital costs	Year 1	Year 2	Year 3
Property purchase	250 000		
Garden preparation	1 000		
Drainage	2 000		
Vehicle	45 000		
Trailer	2 000		
Propagation houses	1 500		1 500
Polyhouses	3 000		3 000
Irrigation equipment	3 000		2 000
Weedmat	500		200

Capital costs	Year 1	Year 2	Year 3
Gravel (no fines)	1 000		
Hot beds	2 000		1 000
Shadehouse	1 500		1 500
Stock plants	2 000	500	500
Hand tools	1 200	500	500
Barrows/trolleys	1 000		500
Computer/printer	2 000		
Potting/workbenches	1 000		800
Office equipment	500	500	500
Office furniture	1 000		
Total capital costs:	**321 200**	**1 500**	**12 000**

Operating costs			
Consumables			
Fertilisers	2 000	3 000	4 000
Pesticides	300	350	400
Hormones	100	100	200
Disinfectant	100	100	200
Spray equipment	500	0	300
Trays	3 600	7 400	8 200
Pots	7 000	14 000	21 000
Soils	3 000	6 000	8 000
Petrol	5 000	5 000	5 000
Stationery	500	300	500
Plant labels	2 000	3 500	5 000
Total consumables	**24 100**	**39 750**	**52 800**

Other costs			
Rates	4 000	4 100	4 200
Insurance			
Car	800	800	800
Building	1 500	1 800	2 000
Public liability	2 500	2 500	2 500
Phone	1 400	1 500	1 600
Power	3 000	3 500	4 000
Water	1 500	2 000	2 500
Advertising	3 000	4 000	5 000
Total other costs	**17 700**	**20 200**	**22 600**

Total operating costs	**41 800**	**59 950**	**75 400**

Projected nursery income

Table 12.10 involves some assumptions, and the figures are largely best estimates. Accurate assessments of costs and profits are impossible and will depend on productivity, sales and labour costs.

Table 12.10: GreenPlant Nursery projected income

This table is based on capital cost written off in the year purchased; this is not usual. Capital items are depreciated over a period of time, the rate of depreciation depending on the item.

Year	Capital costs	Operating costs	Labour costs	Total	Sales	Net profit/loss	Cumulative profit/loss
1	321 200	41 800	90 000	453 000	201 894	–251 106	–251 106
2	1 500	59 950	140 000	201 450	391 248	189 798	–61 308
3	1 200	75 400	180 000	256 600	551 238	294 638	233 330

Table 12.11: Effect on profit and loss, when capital costs are not included

Year	Operating costs	Labour costs	Total	Sales	Net profit/loss	Cumulative profit/loss
1	41 800	90 000	131 801	201 894	70 093	70 093
2	59 950	140 000	199 952	391 248	191 296	261 389
3	75 400	180 000	255 403	551 238	295 835	557 224

Potential profit increases

There are ways of increasing your profit rate beyond the projected rate. If the manager develops a high level of direct retail sales to tourists and other visitors to the property, then retail prices can be charged, which will yield higher returns per plant. For example, a tubestock seedling that might wholesale for $1.10 could be sold for up to $2.50 retail, and as the plant is being sold directly from the nursery there would be no transport costs involved.

It may also be worthwhile to consider limited production of larger container-grown plants for direct retail sales. This could also be a useful way to utilise any excess production of tubestock. Instead of throwing excess tubestock away or using it for on-site plantings it could be potted-up, for example into a 12 cm (4.5") pot. A plant in this size pot may cost $1.50–2 to produce and have a wholesale price of $3, but retail at $6–8. Thus, even retail sales of 2000 × 12 cm pots per annum could add as much as $12 000 to the total annual gross profit.

Sensitivity analysis

A nursery is a business based on living materials, not inert materials which can be put in a storeroom to hold. Plants need constant attention, so there is a need for a sensitivity analysis which involves monitoring items within production which could affect production and the end results of achievable sales.

There are several areas of concern which should be given particular attention, and continually monitored.

Productivity levels

Many nurseries fail due to low productivity levels – in other words, they don't produce enough saleable plants for the labour and money put into the enterprise.

- Initially this may not be critical, but low productivity can be a difficult habit to break. Plants should be produced at a relatively fast rate from the very beginning.
- Workers must know how many cuttings should be done each hour and how many tubes potted each hour, and those standards must be met if those workers are to have a job which pays.
- Work must not only be fast enough to get results, but good enough to get results.
- The tasks which lead to high productivity must be given priority.

A high proportion of time needs to be spent sticking-in cuttings and tubing.

Pests and diseases

Major pest or disease problems can enter a nursery and move very quickly, killing a high proportion of the stock within days. Often, by the time the problem is noticed it is too late.

- Sanitation and a preventative spray control program are essential.
- Fencing will be necessary to exclude animals such as kangaroos and rabbits.

Plant care

Workers need to be rostered so that there is someone at the nursery every day. All plants must be looked over every day, and if something needs doing it can't be delayed. Watering is particularly critical. Overwatering or underwatering can cause losses or lower quality. Pruning, weed control, temperature control, feeding and all other aspects of plant care must be managed properly and continuously.

Propagation material

A shortage of high-quality stock plants can drastically reduce the potential rate of expansion. A suitable supply must be organised well in advance.

Planning production

The varieties grown and the quantity of each variety must be continually adjusted according to changes in market demand. Production schedules need to be written down. Often, nurseries fail because they are too busy growing plants to take the time to work out what they should grow.

Customer relations

All customers should feel good about dealing with the nursery. Anyone who deals with customers must learn to be cheerful and smile a lot. They must always put the customer first and make the effort to give good service.

Financial management

A lot of money will flow through the nursery. If it is misspent, the nursery risks failure.

- The danger of hidden costs must be understood by all concerned.
- Materials and equipment must not be taken for private use.
- Equipment and tools should be well-maintained at all times.
- Cash flow must be maintained.
- Accounting procedures and record-keeping must be good.
- Overstocking of materials can cause cash flow problems.

Marketing

Poor marketing is common in nurseries. The success of a project is partially enhanced by the fact that it may prove easier to compete in the nursery industry than in some other industries, but marketing still must be done properly. Plants need to be presented well, promoted well and transported in a way which minimises any damage. Chapter 13 offers more information about nursery marketing.

Insurance

Inadequate insurance cover can lead to unexpected costs. Insurance means that when (not if) things go wrong, the nursery can manage the expense of rectifying the problem.

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13

Marketing

Marketing is essential if a business is to be profitable. No matter how good your product is, if your customers cannot find you it will not be possible to make a sale. There are many different ways of marketing nursery products and services. The type of marketing depends upon the product or service, the type and size of the business, and the business plan.

Marketing nurseries

Retail nurseries

Retail nurseries are those that offer their products and services directly to members of the public. Marketing options include:

- shops such as garden centres or nurseries which concentrate on selling plants, or sections inside other shops such as supermarkets, hardware stores and florists;
- specialist nurseries that concentrate on growing one particular type of plant which is sold direct to the public from the nursery. This type of nursery may also sell plants wholesale;
- mail order – this is usually conducted through catalogues and magazine advertisements;
- trade shows, home shows, agricultural field days and other such events used as an outlet for plants;
- market stalls such as those at craft markets, fruit and vegetable markets etc. Some nurseries find that regular attendance at a market can make a significant contribution towards sales. Markets may also be used on an irregular basis to clear excess stock.

Figure 13.1: Trade shows and expos can be a simple way of raising the profile of your nursery, to a highly targeted audience.

Wholesale nurseries (production nurseries)

Wholesale nurseries usually sell products in bulk to other businesses. Marketing options include:

- trade markets conducted by industry associations or private markets where producers can sell to retailers, landscapers and other industry people at wholesale prices. Members of the public are usually excluded and market organisers usually charge participating nurseries a fee or commission, or both;
- truck sales where a vehicle loaded with plants calls on retailers and usually sells direct from the truck. Some wholesalers use a smaller vehicle with stock samples to stimulate sales;
- agents that take a commission from the wholesale grower to take responsibility for marketing the product. This method is only worthwhile if the agent can provide a greater return than if the product was marketed by the wholesale business itself.

The marketing mix

The marketing mix is a combination of practical rules and flair. It entails the setting of sales targets, making objectives, strict control and measurement of sales and profits – all combined with effective presentation and display. Marketing can be described as a combination of these interconnected factors:

- products and services;
- promotions and advertising;
- packaging;
- transport and distribution;
- sales;
- after-sales service;
- market research;
- marketing budget;
- legal implications of marketing.

Products and services

The nursery industry provides a wide range of products and services.

Plants (green life)

The majority of sales are usually plants, seed or flowers. These can include natives, trees, shrubs, groundcovers, climbers, perennials, herbs, bulbs, indoor plants, cacti, bonsai, topiary, potted colour, hanging baskets, terrariums, vegetable seedlings, berry plants, fruit trees, instant turf (sod), cut flowers, lawn seed, flower seed, vegetable seed and tree and shrub seed.

Allied products

These are things purchased to help grow plants better, or to be used in landscaping. They provide add-on sales when customers buy plants. These include fertilisers, stakes, pots, mulch, soil additives, tree guards, chemical sprays, tools and equipment, horticultural fabrics, soils and potting media, hydroponic equipment, irrigation/watering equipment, garden buildings, fencing, rock and stone, masonry, concrete, timber, garden furniture, statues, ponds and pumps.

Services

Nurseries may have experts on staff to offer some special services free or at a charge. Alternatively, they may develop a relationship with local experts to provide such services. These services can include landscape design, delivering plants, identifying pest and disease problems, tree surgery, lawn repair, garden renovation, chemical spraying, routine garden maintenance, landscape construction, installing irrigation systems, erecting grden buildings, transplanting, pruning, recycling (refunds for used pots, chippings, prunings etc.), entertainment (eg. a guitar player or clown), a garden advice booth, garden lectures and courses.

Allied services

Allied services are those that have a synergistic relationship with the nursery operation. They include franchises and business partnerships. For example, there is a strong trend in retail nurseries to add a tearoom or cafe to their operations. As well as generating income, these facilities encourage customers to spend longer in the nursery, increasing the likelihood they will make a purchase.

Other

There are many other things which may be included in nurseries to generate extra turnover. They should be relevant to the type of nursery, and the type and number of customers. They can include self-service drink or snack food machines, books, magazines, art and craft, cards, souvenirs, aquarium supplies, pet shop, hardware supplies and pool and spa supplies.

Choosing a plant variety to sell

Plants must be selected according to their potential to return a profit. Plants that are too easy to grow will not command a high price. Plants that are difficult to grow may be too expensive to produce. Choose plant varieties according to the capabilities and resources of the nursery. There are a number of issues to consider when choosing a plant to sell:

- climate;
- available space;
- ease of propagation;
- amount of time and effort required for maintaining the plant before sale;
- irrigation and fertiliser requirements;
- pest and disease susceptibility;
- need for shelter and light.

It is preferable to select plants that can be easily grown under existing conditions. For example, if you have limited water and live in a dry climate, you might do better to grow drought-tolerant succulents, rather than struggle with water-loving plants. The following issues should also be considered:

- plants that are healthier and not potbound are more likely to grow faster and overcome the effects of disease or insect attack;
- larger plants often take more time and effort, but produce higher financial returns;
- plants with a uniform shape, straight stem, uniform branches and a good coverage of leaves are more attractive to customers;
- plants covered with flowers are more appealing to customers;
- plants that have been stored in a shadehouse or other protection may need acclimatising after transport;
- remove or treat plants with any sign of insect attack or visible disease. Not only are these plants less attractive, they could devastate the rest of the nursery;
- a clean and tidy site where health concerns are readily observed is more likely to produce healthy plants than one where cuttings are left lying around, compost is left exposed and pots are not sterilised before reuse.

The range and diversity of plants available is an important issue for nursery retailers. Wholesalers may require a certain diversity, but to a lesser extent than retailers. Retail consumers expect to obtain an extensive range of plant and non-plant products from one outlet and prefer not to have to shop in a number of outlets.

Product case study: marketing cut flowers

The cut flower industry provides an interesting example of how plant producers have to select plant material and adapt their operation to suit both wholesaler needs and market demand. Only certain types of plants produce flowers suitable for this industry.

Product grading

A grower grades flowers according to established quality standards. Flowers are packaged with the grade described on each box. If there is a delay in selling the produce and it is deteriorating, the wholesaler may reduce the grading, thereby reducing the selling price.

Produce is usually graded at premium, first and second. A standard bunch is 10 stems. This quantity has been agreed to allow orderly marketing and so buyers always know how many flowers are in the bunch. Typically, small flowers are sold in multiples of 10 and very large flowers are sold in bunches of 6.

Leaves and branches are preferred to be 30–50 cm (12–20") long, for ease of handling. Foliage must be clean, unblemished, mature and well-coloured. Immature tips of leaves or wilting branches should be removed. Stems should be relative to the size of the flower – larger flower stems should be 40–50 cm (16–20") long.

Packaging

Packaging of produce is standardised for convenience. A set weight per box for produce and set number of flowers per box is the accepted standard. Producers must overfill the box to allow for weight loss during storage, and the packaging weight cannot be included. Government inspectors from the weights and measures department randomly count and/or weigh produce to ensure consumer protection.

Most produce is packaged in cardboard boxes. A cardboard box minimises product deterioration in refrigeration and is durable enough to withstand manual handling. Most boxes are reusable. Many retailers keep the empty boxes to be collected with the next delivery, and reused. Packaging is expensive – not only the cost of the box, but also the labour content involved in folding and storing. The industry has endorsed a recycling strategy. Flower boxes are cardboard, lined with cellophane to reduce extra moisture loss. Although the cellophane is rarely recycled, the boxes can be.

Conditioning for market

Flowers sometimes need to be hardened-up before being packed and sent to market. This may involve standing in cold water to allow turgidity to reach optimum level before the flowers are packed dry and sent to market. The water often contains a flower preservative and bactericide.

Contract growing

Many primary producers and retailers engage in contract growing, where the parties enter into a formal agreement to provide a quantity of produce over a set period of time at a set price. Growers often prefer this arrangement as it guarantees price and sales, and avoids the fluctuating market prices. Retailers are assured of a regular and high-quality product that they do not have to continually source.

Marketing to the wholesale market

With this method, the producer contracts with a wholesaler to sell produce at the central markets to the highest bidder. The produce must be boxed and delivered to the markets where the wholesaler has a stand. The wholesaler then presents the produce for sale to on-site purchasers or sells the produce via telephone orders from their customer base. If there is surplus material, often the wholesaler will auction the produce to sell it before it deteriorates. The wholesaler usually charges a commission of 8–10% for the service.

Wholesalers

Wholesalers purchase produce from the markets, usually from another market wholesaler. They then onsell the produce in smaller quantities to retailers. The wholesalers' service includes small quantities of a large variety of produce, and delivery of the product. They buy from the markets at reduced rates and sell to retailers at a higher price. Wholesalers are a good target market for producers, as they will purchase directly from producers at a higher price than the markets and order sufficient quantities for delivery to be economical.

Supermarkets

Supermarkets purchase very large quantities of produce and enter into supply contracts only with large suppliers who can guarantee constant supply. Many of the large chain supermarkets have contracts with one or two market wholesalers, to reduce office procedures. They tend not to deal directly with primary producers.

Local retailers

Often, small primary producers form an alliance directly with retailers. Retailers and suppliers purchase produce from the markets, but if they can purchase directly from the grower, they will. Direct purchasing allows retailers to receive fresh, high-quality produce regularly and reduces the volume they have to transport from the markets. It also cuts out the middleman. Producers benefit from an increased price, but the downside is that they have to deliver smaller quantities to several outlets.

Export

Quarantine Inspection Service requires that all horticultural products exported from any country be inspected for pests, disease and residues on behalf of the importing country, and in compliance with agreed standards and protocols. After inspection, a certificate of inspection must be sent with other paperwork to the importer. This is referred to as the phytosanitary certificate.

Promotions and advertising

Messages

For a successful promotional campaign, the messages being presented should all relate to and support one common idea. For example, if the common idea is that the nursery offers a fantastic service then every promotional exercise in a campaign should support this by mentioning the quality of service. One advertisement might emphasise that the staff are very skilled. This might be followed by a press release saying the nursery will offer a free plant to any customer who has to wait more than two minutes to be served. Both advertisements focus on service.

Different promotions must be quickly identifiable as being for the same nursery. This can be done by using the same colours on all literature, by using the same prominent logo, even by using the same font in all printing. Some nurseries achieve uniformity of presentation by using the same voice or face in all advertisements.

Promotions can only work effectively if the basic merchandising job has been done properly. They are not a substitute for product range, siting and space allocation arrangements, and well-controlled displays.

Message generation

You need to develop a message that convinces customers to want or need to buy the product offered at your nursery. Ideas from professionals, experts and customers may all be helpful. Attempts to convince customers of the benefits include:

- a social reward – for example, having a garden that is suitable to the surrounding district or gardens;
- a rational reward – for example, developing a garden that uses a sprinkler system that saves water and time in the garden;
- an ego reward – for example, having the nicest garden in the street or town or having the latest-release plants;
- a sensory reward – for example, having a garden full of scent in spring.

Selecting and evaluating a message

Consider messages in terms of desirability, exclusiveness and believability. The strength of a message depends upon the strength of these three factors. If any one factor is weak, then the message loses strength. The message should always state something desirable and interesting about the product or service, and should be distinctive to that product or service. The message must be both believable and provable.

Delivering a message

The impact of a message depends not only on what is said, but also how it is said. Non-verbal promotion is as important as verbal. You must decide on the style, tone, words and format to be used. Select the factors that will put the message across in the most effective way. For example, the following styles can be used:

- life-style – emphasise how the product fits into a particular life-style, such as the use of garden furniture to show leisure;
- fantasy or mood – create a fantasy about or around the product, such as describing how to create a restful rainforest in the garden by using specific plants and ponds;
- technical expertise – show the technical expertise behind the product or service, particularly for industry leaders breeding and supplying a particular plant;

- scientific evidence – present statistical, survey or scientific evidence to support your product. For example, show the higher yield from new varieties of vegetables;
- testimonials – credible persons such as other customers or gardening experts can endorse a nursery or product.

The tone of a promotion can vary from serious to frivolous and humorous. Serious advertisements avoid distracting from the message. Light-hearted advertisements attempt to convey the message in a more subtle and indirect way.

Customer relations

Promotions can be used to achieve the following objectives:

- attract extra customers to your garden centre – you clearly need to advertise or announce the promotion in your advertising;
- encourage customers to buy more when they visit your garden centre – mount feature displays on related products. For example, promote rose food while featuring rose plants;
- encourage customers to visit you regularly for all their garden needs – you need a planned and sustained program of promotions so that you always offer some inducement to your customers.

Figure 13.2: Display gardens within a nursery or garden centre demonstrate to customers how products can be used. They are an excellent marketing tool.

Figure 13.3: This easy-to-use, self-service 'bulb bar' is an example of an innovative display technique in the shopfront of a nursery.

Although every nursery business is different, the following are the most common ways of making contact with clients or customers:

- local newspaper advertising;
- daily newspaper advertising;
- magazine advertising;
- letterbox drops;
- direct mail promotions;
- telephone book;
- shopping centre displays;
- exhibitions or trade shows;
- radio and television advertising;
- press releases;
- word of mouth – through friends, clubs, professional bodies etc.;
- visiting direct approach – travelling sales representatives calling on customers;
- telephone sales;
- establishing agents – local nurseries etc.

One of the most basic rules in dealing with customers is to make every person that has been good enough to walk through your front door feel wanted. Without customers, you simply would not have a business.

Publicity marketing

Publicity involves obtaining exposure for a product or service through the media, without paying for it. It may include such things as press releases which lead to radio interviews or articles in newspapers, and conducting events or activities such as product launches that attract media interest. Publicity is based on the following principles:

- high credibility – news or features seem more credible than an advertisement. An article about the introduction of a new product gives the product more credibility than an advertisement does;
- catching people off-guard – people who might avoid advertisements or other sales approaches will often read an article or listen to a news item about a product or service;
- dramatising products or services – special events can be attached to product launches as a way of dramatising the product. For example, someone might be given the product to use on a round-the-world trip to dramatise how the product could be used.

Public relations can be applied in the following areas:

- press – where newsworthy information is put before magazines and newspapers;
- product publicity – specific products or events related to products or services are brought before the news media. This brings goods or services directly before the public through promotions, displays, appearances and demonstrations in public places such as exhibitions, shopping centres and busy streets;
- corporate communications – communications within and between businesses, aimed at letting potential users know about certain products or services;
- lobbying – efforts aimed at influencing government, in an attempt to maintain or change desirable legislation.

Promotions case study: writing a press release

Understand the editorial needs of the publication to which you are sending your press release. Editors are most likely to print a press release in the following situations:

- when there is a gap in the publication that must be filled quickly and your press release is the nearest thing at hand;
- when the press release fills a gap in the publication because it is the type of thing that is difficult to get. For example, if it is a special event and the editor usually has trouble getting details about events;
- when it says something that the editor has a particular leaning towards. For example, if the editor is enthusiastic about organic gardening, make the press release highlight organic issues.

Be aware that the editor might drastically change or shorten your press release if they are not totally happy with what you send. Your own version should be the best, so try to get it right before sending it. The text should still make good sense even if sections have to be cut out because the editor only has a small space available.

The heading is the most important thing. It must be different and attention-grabbing. The first phrase of the first sentence must grab attention and be clearly relevant to the whole press release, because after the first sentence the reader will decide whether to continue or stop reading. The second sentence must be more attention-grabbing than the third, and the third more than the fourth and so on, throughout the whole press release.

Clarity is very important. All types of people should be able to easily understand your writing. Avoid big or difficult words. Keep it all simple. Similarly, conciseness is extremely important. Always use the minimum number of words. Look over what you write and rewrite it to use fewer words wherever possible. A press release can be as short as 60–100 words, or as long as 1000 or more words. Generally, smaller press releases are more likely to be printed.

It must capture the interest of readers, so you must understand the readers. Some publications have a readership which reads every word thoroughly; others have readers who tend to look at the pictures and read only the headings on articles unless their attention is particularly caught. Don't make it sound like an advertisement – publishers don't print press releases that sound too much like free ads. Your name, address and phone number should be included for further information but your promotion must be subtle.

Present your press release as a double-spaced, typed document, on white paper with the words 'Press Release' in the top right-hand corner. Include a photograph if possible. Post press releases to newspapers 1–2 weeks before your preferred publication time. Post to magazines 3–4 months before publication. Fax to radio and television stations a few days before you hope to have them broadcast.

Packaging

Packaging is the way a product is presented for sale. In a retail situation this is quite different from a wholesale nursery. In retailing the customer sees almost everything, so every plant should be in perfect condition. Floors and shelves should not just be clean; they must also look clean, neat and tidy. In a wholesale nursery the customer might not see much, so even though cleanliness is important things don't always have to look so perfect.

Production (wholesale) nurseries

Above all, plants need to be packaged in such a way that they are not damaged in transport. Other aspects such as staking, the type of container and labelling are of secondary importance. These extra things can make a difference to sales, though, particularly when plants are being sold to retailers for resale. Retailers always appreciate packaging that is easier to handle and which can be displayed for sale with the minimum of fuss. Many of the packaging issues described below also apply to retail nurseries.

Wrapping

Individual plants may be wrapped in cellophane sleeves to protect foliage and improve appearance. This is often done for indoor plants and potted colour. Complementary colours can be particularly eye-catching.

Labelling

Tubestock is often sold with only one or two labels to a tray, which may be appropriate where plants are to be repotted or planted to nursery rows for growing-on. When plants are sold to retailers each individual plant should be labelled. Everything else being equal, retailers will tend to buy plants with better-quality labels. Some wholesalers even supply point-of-sale material to retailers, such as posters, information sheets or display tags with a photograph and basic cultural information on a plant. This type of service makes life easier for the retailer and generally improves sales, making that plant line more worthwhile for both the wholesale grower and the retailer.

Containers

It is better to standardise containers for particular lines, in terms of colour and size. Some nurseries will grow one type of plant in one size container and others in a different size. Perennials and herbs are often grown in smaller containers or square containers, while trees and shrubs in the same nursery might be grown in larger containers. Some nurseries, for example, colour-code their plants, growing all natives in one colour container, trees in another colour and shrubs in a third colour. The choice of container is influenced by what is best for plant growth, but marketing considerations are also very important.

Stakes and trellises

Climbers need a stake or small trellis to prevent their stems intermingling with neighbouring plants. Other plants sometimes need stakes to support weak stems or to help train growth in the nursery. The type of stake or trellis can add significantly to the cost of production but, depending on the type chosen, can also greatly improve the marketability of the plant.

Boxes and trays

These are used to move plants about. They might be made from wood, plastic, metal or waxed cardboard. Their cost can be considerable and some wholesalers choose to recycle trays or boxes, asking customers to return them. When plants are sent through freight services, recycling can be difficult. Some boxes are not particularly attractive, having been designed to simply move plants easily and safely. Other boxes might be designed to display plants in a retail situation. This type of box can help boost sales significantly, but it will also add to production costs and inevitably mean a higher retail price.

Retail nurseries

Fixtures and fittings

These can be more expensive in some businesses than others, and have a great deal of impact on the character or image of your shop. Shopfitting companies, or tradesmen trained in shopfitting, can provide ideas and a professional service in this area. Display stands and display bins are frequently supplied at no cost to retailers who stock a particular product line. For example, one seed company may supply a display stand but another company supplying a similar product might not.

Layout

Retail shops are usually divided into three main areas or departments:

- major product areas where the better-selling products are highlighted. Here, selected lines are prominently placed so that they can be clearly seen by virtually everyone who comes into the shop, to encourage their sale. These areas include the window display, displays which are obvious from the front door, and the counter;
- departments where goods which relate to each other are grouped together. For example, in a retail nursery, seedlings are put into one area and indoor plants are put into a different area. The departments should relate to each other by locating related plants and products next to one another;
- the service area from which people are served, consisting of the cash register, credit card facilities, leaflets/brochures, wrapping facilities etc. This should be located in a position from which all parts of the shop are visible. For both service and security reasons, it is generally best located near to entry/exit points.

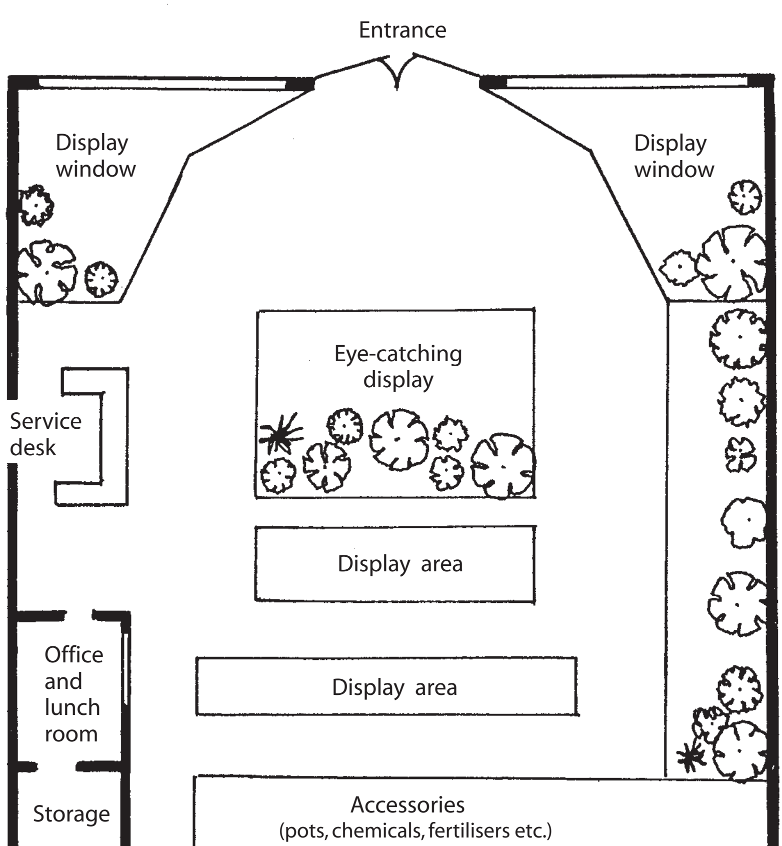

Figure 13.4: Layout of a small retail plant shop.

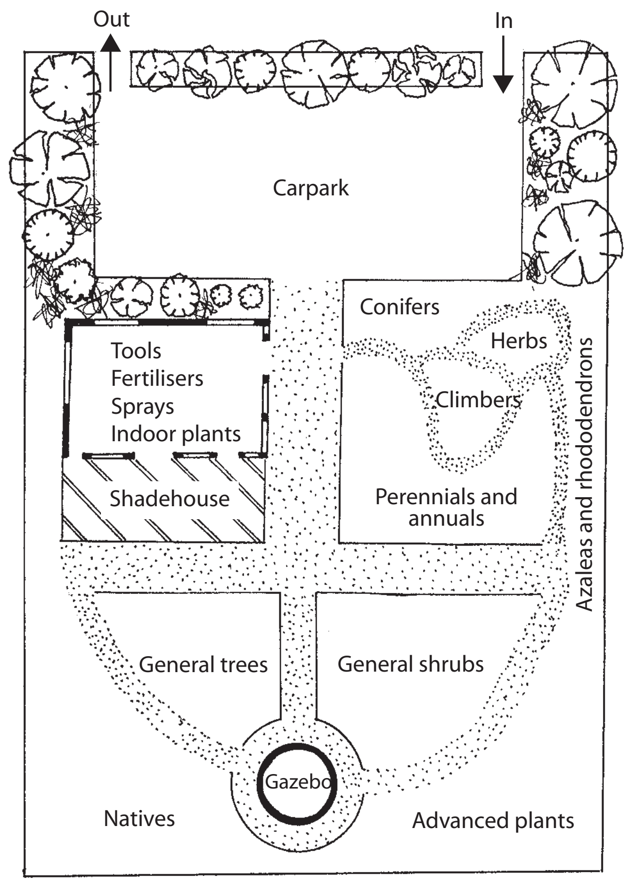

Figure 13.5: Layout of a retail nursery.

Signs

Many people like to make their own decisions with minimal help from salespeople. Thus signposting is one of the most important tools for communicating with customers in a nursery. The disadvantages are that signage requires time for development and maintenance, and can seem expensive. The advantages are that signs provide an excellent training program for new employees as well as give information and sell merchandise.

Signs must provide all the information necessary for customers to make their decisions with ease. So write signs from a customer's point of view and make sure all relevant information is given so that they can make a buying decision. Ensure every sign reflects your image and is a presentation of your knowledge. 80% of customers wait on themselves and 80% of customers' plant questions can be answered with the use of signs.

Professional signwriters are best employed for one or two major signs. If expense is a factor, other signs may be obtained through wholesalers that provide posters and display signs at no cost. Shopfitting or stationery suppliers can supply some ready-made signs such as 'Pay Here' and 'Do Not Touch'.

Plant signs
Every plant should have certain information with it. This includes why customers should buy it, what it will do for them, how to plant and care for it, what they need to buy with it, how much it will cost them and information on its growth. The sign should also attract attention and be pleasant to look at. There are a number of rules for plant signs:

- always tell the truth;
- make it readable;
- use laypersons' terms;
- assume customers have no knowledge of the plant;
- present information that customers want to know;
- explain words and activities that suggest special knowledge;
- be consistent in the size and placement of signs.

Display
If products are displayed well, they sell well. The best-selling products should always be displayed in the most prominent positions.

The prominent positions are point-of-sale positions, and where things will sell most readily. Examples of point-of-sale positions include window displays, the main counter beside the till, the ends of rows, islands in open parts of a showroom floor and points close to entry and exit. Products placed at eye level tend to sell better than those below or above eye level.

Colourful products displayed in mass groups of twenty or more will create impact, whereas one plant mixed among different plants may go unnoticed. Feature products with large signs which highlight their selling points. For example, if you think a discounted price will sell the product, you need a large sign at the product, saying 'Discount'.

People can become suspicious if there are only a few items on display. The nursery looks healthier if it has a quantity of plants on display. Customers have more confidence in both the product and the nursery if there appears to be an abundance of a particular product.

Spacing
Customers shy away from cluttered, confined spaces. If products are displayed with plenty of space between the products and in the surrounding area, that part of the shop is more likely to be visited. Aisles should be wide enough for people to pass, but should not be long. People should be able to leave one aisle to go to the next without having to walk very long distances.

It is most important not to overclutter items and to leave space between different items, so that customers can find different lines easily and access them without a mass landslide to the floor!

Note where most people stop and look at things in your nursery, and try to determine why they choose those areas. Also notice dead areas, and try to determine what can be done to attract people into those parts of the nursery.

Packaging case study: retail nursery lighting

With marginally extra cost you can drastically increase the visual effectiveness of the retail nursery space. Well-lit areas attract customer attention. Dull areas repel customers. The amount of additional light each area needs depends upon the direction of natural light and the position of the buildings, shadecloth, trees and other fixtures that shade the nursery. There are many issues to consider when creating light conditions inside a retail nursery. They include:

- major product areas must be highly visible;
- point-of-sale locations should be highlighted with extra lighting;
- light fixtures must fit the décor;
- lights must not create glare from unshaded globes;
- there is no point lighting areas that won't be seen;
- areas that are shaded for part of the day can be lit automatically by a sensor light or an automatic controller;
- safety lighting must be installed. If the nursery operates at night, places such as entrance areas and steps must be illuminated for the safety of customers and staff.

Selecting lights

Different lights give off different wavelengths of the colour spectrum. The colour given off by artificial light can alter the colours of plants and other items on display. Lights have cool or warm tones, depending upon the type of globe being used. Some lights are suitable for growing plants indoors, whereas others are more suited to illuminating car parks. The coloured filters or bulbs available for some light fittings can also significantly alter lighting effects. Similarly, different grades of shadecloth can change the ambience and colours of a particular area in the nursery.

Positioning lights

Many fascinating effects can be achieved through focusing light in different ways.

- Selective lighting creates a dramatic effect. For example, a spotlight shining on a single statue or tree amid darkness is much more effective than a mass of floodlit trees and shrubs.
- Rhythm can be created by a series of evenly spaced lights, such as a single narrow stream of light on each tree in a row of evenly spaced trees, or a series of evenly spaced lights along a wall or hedge. This technique is excellent when it comes to lighting paths and steps.
- Placing a spotlight close behind an object and casting a shadow onto a wall or other surface creates shadows. This is useful for accentuating sculptures and architectural plants.
- Hiding a light behind an object will silhouette it against a backdrop such as a wall. This will enhance the object.
- Placing lights up high so that the light filters through branches etc. creates a moonlight effect. For example, lit tree branches cast moving shadows on the ground as they blow in the wind.

Transport and distribution

Nurseries need to move plants from the seller to the customer. Transport can be handled by the nursery itself, or subcontracted to carriers such as trucking companies, rail services or, in some cases, postal services. Whatever method is used, attention must be given to moving plants fast, at a competitive price and without causing any damage. In addition, paperwork is important when shipping. Accurate records must be kept of what is shipped and what is received by the buyer.

Retail nursery managers who need to visit wholesalers or markets to buy plants will need an appropriate vehicle or trailer to bring plants home; even those who don't will probably need transport to deliver plants to customers who don't have their own transport.

Wholesale nurseries need a vehicle or vehicles to deliver plants to retail customers or, when using rail services, to deliver to the railway station.

Some plants such as bulbs, perennials and deciduous trees and shrubs go through a dormant period when they are far less susceptible to damage in transit. The production and marketing of these plants is usually timed to coincide with the dormant period. They are usually cheaper to ship and more economically viable to package because they can be shipped without soil, and numbers of plants can be packaged together.

Plants that are transported with soil around their roots must be packed so that plant will remain in good condition. Be careful that plants do not move in transit, tipping soil from containers or damaging foliage. Plants that are in transit for several days during hot weather may dry out and suffer serious stress. Even if a customer has prepaid, return business will be unlikely if plants are damaged in transit.

Government regulations of states and countries restrict the movement of both soil and plant material. If you are shipping interstate or internationally, check the regulations first. Quarantine is vital to protect the horticulture industry, especially within Australia. Some plants can travel within Australia with no problems, but some plants and/or potting medias are restricted. Plants can carry diseases and insects, which can rapidly infect areas. Potting media can also carry disease, insects and weed seeds. In some cases it is necessary to obtain permits to move plants from one region to another.

Tissue culture is sometimes an easier method of transporting plants, especially if importing into Australia. Australia has restrictions on the importation of plants, and plant parts. Heavy fines are levied if people fail to meet quarantine requirements.

Transport case study: container plants for Mother's Day

The horticulture industry operates on a very seasonal basis, so it is important to plan promotional activity for key products during the period that generates the biggest demand. Most plants only flower for a certain time of year and for marketing purposes it is desirable to promote plants when they are in flower. One way this can be done is to promote the flowers in conjunction with annual festivals such as Mother's Day.

The short window for sales requires the precise production and supply of plants for a specific date. Therefore, delivery of products for sale must be prepared well in advance. Seeds must be sown and plants grafted months, or even years, before the time of sale. Sufficient transport must be arranged to deliver stock in perfect condition and on time.

Mother's Day

In Australia, Mother's Day falls on a Sunday in May each year, and is important to many families. Many people choose to give their mother flowers on this day.

Although a boon for plant sales, the problem for producers, wholesalers and retailers is the very short time frame for sales. Therefore, stock has to be well-prepared and delivered on time ready for sale. Quality has to be uniform and of a high standard to attract customers who are often buying at the last minute. Poor-quality plants are not acceptable at this time.

Plants sold earlier must feature flowers that will survive from the time of purchase until Mother's Day. For example, plants sold days before should feature lots of buds, rather than open flowers. This can necessitate adjustment of growing conditions to slow or accelerate flowering.

The key to the success of a Mother's Day plant in a container is its capacity to deliver a product that will last longer than a bunch of cut flowers, thus providing after-sales benefit to the person receiving the gift. The container and accompanying label are also important contributors to the value of Mother's Day container plants.

Plant selection

Container plants for Mother's Day must be ornamental, uniform and capable of mass production by a particular date.

Chrysanthemums and other daisies are the traditional Mother's Day flowers, available in a wide range of colours. Chrysanthemums also grow well in pots and are suitable for a sunny, sheltered position.

Some other long-flowering plants suitable for Mother's Day pot plants include:

- african violets – in good growing conditions, flowers are produced for several months each year. Don't let the sun shine directly on their leaves, and don't allow the leaves to get wet when watering;
- cyclamens – flowers will continue through winter until early to mid spring. They like a cool sheltered position away from heaters, direct sunlight and draughts;
- pansies and violas – flowers are produced for several months;
- roses – some roses are still producing flowers at this time of year, especially in warmer areas. Keep them well-lit and warm to extend the flowering time as long as possible;
- camellias – the Sasanqua varieties are early-flowering. Individual flowers last only a few days but there are lots of them;
- succulents and cacti – are hardy easy-care plants, ideal for non-gardeners. They feature ornamental foliage or shapes that can substitute for flowers;
- peace lily (*Spathyphyllum*) – this hardy indoor plant has large white flowers for long periods. It grows well outdoors in warmer climates in a shady position;
- poinsettias – the bright-red leaf bracts can be stimulated by providing shady conditions.

Sales

Wholesaling

Wholesalers can sell to customers the following ways:

- taking orders to grow (contract growers);
- calling on retailers (sales reps);
- at trade days or wholesale markets;
- through agents;
- franchising (having the right to sell a company's plants or services in a particular area);
- nursery sales to retailers, landscapers, councils etc.

Retailing

Retailers can sell to customers the following ways:

- shops – the common retail method. May be a large garden centre/nursery or a small shop in a shopping centre. Many costs involved but easily accessible to the public;
- mail order – selling plants and associated services/goods through the mail. Advertising and promotional work is essential to gain customers who send away for your goods. You do not have the costs of a retail outlet such as positioning and related costs, browsers and salespeople;
- markets may be once-off or a contract stand. Competitive prices are expected. Not all markets are open 5–7 days a week, although most are open at weekends. A good way of selling poorer-quality or end-of-line stock. Good alternative for a person beginning a backyard business;
- party plans – a form of selling to a 'party' of people. Organisation is done through a host who provides the venue as well as drinks and nibbles for guests. If a certain amount of produce is sold, the host receives a gift, such as a plant of their choice;
- hawking – selling from a vehicle or trailer at the roadside. Depends upon passing traffic to stop. Few costs involved. Most local councils require a hawking licence for specific areas.

Sales staff

In the nursery situation, plant knowledge and cultural information are among the most important requirements of staff. This can be disadvantageous for new staff with little plant knowledge. Teach them that customers prefer to wait while they find out the right answers, rather than be given incorrect information. Signage around the nursery will help.

A good salesperson should possess the following characteristics:

- good appearance;
- pleasant personality;
- courtesy and tact;

- enjoyment of selling;
- basic understanding of human nature.

Every salesperson should know:

- details of the product or service they are selling – its attributes, its competition and its negative points;
- where and how to find the product/brochures/catalogues/order forms and anything else relating to the sale;
- the correct price and the terms of sale;
- procedure for making a sale, including using the cash register, filling out the order book, writing receipts etc.;
- company policies on returns, damaged goods etc.;
- how to package or deliver goods and services, such as wrapping and directing other staff to deliver plants;
- how to keep records in order;
- how to maintain order and tidiness in the sales area.

Key rules every salesperson should follow:

- research your customer and product first;
- get your customer's full shopping list before you start. Gently introduce them to products that will complement the ones they want, such as orchid mix for an orchid plant;
- remember that most customers are open to suggestion and want their plants to grow well, so help them achieve these goals;
- highlight the benefits of a product, rather than the features. For example, tell the customer what it can do for them personally. Don't tell them what is great and unique about the product if it is not relevant to them in particular;
- if there are objections, play it cool and try to work out exactly what they are. Once you narrow down the objection, put it into perspective by showing something about the product which compensates for the problem. For example, 'Yes, it is expensive, but it will do more things/last longer/be a feature of your garden'. Don't act as if you have won a point;
- always keep control of the conversation. Don't let yourself get into a defensive position; ask questions when the customer starts to take the offensive;
- do not talk while giving a demonstration. Show them, stop and talk, stop talking while you show them again;
- handle products with respect;
- get the customer to try the product;
- if you need to, use the phone or calculator to buy thinking time;
- try to close the sale – ask for an order at the appropriate time, when the customer seems likely to buy;
- fulfilling the customer's needs is more important than improving your own knowledge or sales technique;
- remember that the customer is always right – without them you are not going to remain in business.

Customers

Customer motivation
A professional salesperson must understand what motivates consumers to buy, whether it be a need, the price or the quality of the product. The following points provide an appreciation of buyer motivation.

- There is a motive behind every human action.
- There is always a prime motive and subsidiary motives.
- The salesperson, while concentrating on the prime motive, must never overlook the subsidiary motives.
- Different buyers buy similar equipment, but often for different reasons. Selective motives should be used when applicable.
- There are rational and emotional buying motives, and the importance of emotional motives should never be underestimated.
- The salesperson's objective should always be to include, in the sales talk, the motivational force which will impel the buyer to buy.
- Buyers first fulfil basic needs, but often do not recognise their real needs.
- Benefits should be personalised.
- A salesperson turns needs into wants by proving benefits to the buyer or their company.

Types of customers
Within a short period, a professional salesperson can recognise which type of buyer they are dealing with and can vary the sales technique accordingly. In retailing, shoppers can be categorised into the following groups:

- thinking shoppers – thinking shoppers require facts;
- feeling shoppers – feeling shoppers will respond emotionally to a salesperson's plea;
- intuitive shoppers – intuitive shoppers believe that they have extra sense, some insight which allows them to arrive at the right decision more often than others;
- economic shoppers – these are most interested in prices, value, product quality and economic factors. They are not so interested in treatment by staff, store décor or location etc.;
- personalising shoppers – they enjoy the interaction with sales staff, preferring to shop with sales staff they know and like;
- ethical shoppers – they avoid large chain stores or companies which tend towards monopolies. They also avoid dealing with products which they consider unethical. For example, they don't shop at big supermarkets and prefer to buy food from the biodynamic shop because the food there hasn't been treated with chemicals;
- apathetic shoppers – people don't like shopping and go to the most convenient supplier because they must.

Sales technique

Timing

Timing is always important. There is no point in selling something that cannot be supplied. Therefore, any marketing concept should include targets for the desired level of sales to be achieved at particular dates. Many businesses set and revise monthly sales targets. Others work to a weekly or annual target. Nursery businesses may increase or reduce their marketing effort in order to reduce or increase their level of sales. For example, to maximise advance orders, a specialist wholesale nursery might advertise heavily during the three months prior to bare-rooted tree stock becoming available.

Opening a sale

Conditions have to be suitable before a sale can take place. Recognising an opening and creating the right conditions can give most salespersons a great advantage.

Remember, time is money for you and the customer. People have a limited attention span. If you want someone to know something, get straight to the point! Good marketing involves getting information across to the customer/client clearly and in as short a time as possible. This might be done in many different ways:

- by talking;
- literature – writing, pictures, diagrams;
- video, internet presentation, practical demonstration;
- signage.

Advising a customer what to purchase

First, determine the customer's needs without prejudice. Do this by asking questions. Most people appreciate it if you take time to help them focus on their real needs.

Sales staff in any nursery, retail or wholesale, must know the range of plants, products and services being offered for sale. This is one of the most important skills for a nursery salesperson. Products or services can be described in terms of the following criteria:

- quality;
- cost;
- durability/life-span;
- supply;
- back-up service – ongoing advice/training/maintenance etc.;
- flexibility and diversity of use or application.

Obviously, it can sometimes seem unproductive to spend an hour advising someone on the sale of one plant, but such situations are rare and, even then, the happy customer will return and perhaps bring friends.

Convincing the customer

What makes a buyer nervous of a salesperson? When they know that an attempt is being made to force them into a line of action. A first-class salesperson never betrays this type of determination. Buyers like to feel that they are making their own decisions. Obviously this all takes place through the use of verbal or written communication.

Anything you try to sell has good points and bad points, and you must convince the client/customer that the good points outweigh the bad points. To do this, salespeople must believe in what they are selling.

Bad products and services can be sold, by salespeople who exaggerate the good points and hide the bad points. This isn't good marketing, though, because it can cause problems in the after-sales stage of marketing. If the product or service is not good, the salesperson is advised to seek product improvement.

Add-on sales

A big push in the nursery industry is add-on sales – additional products that can be sold with a primary product. For example, the primary product is a pot plant and the add-on sales opportunities are fertiliser, pest control, new pot, watering can etc.

This can help increase the sale per customer, but some customers may reject the sales pitch and refuse the initial primary product. For example, if your customer has a certain amount of money to spend, they may hesitate about favouring one product at the expense of another. It can cause an 'I'll need to think about it' put-off. It is best to identify your client's priority and to meet that need. Once that need is met and the product is in the trolley (and sale is guaranteed), you may then identify the next priority and help to sell that. Do this again and again in terms of your customer's needs.

Closing a sale

The 'crunch' in the car trade is when a salesperson has reached the stage where the sale is about to be completed. In other words, it is the crucial moment when the sale is about to be 'closed'. Closing a sale is not a skill easily learnt. There are a few simple rules but, as times change and competition for the almighty dollar increases, it is vital for any retail person.

In the nursery industry the closing of a sale (COS) is the culmination of the whole act of selling (from first introduction of yourself, introducing your products and 'preaching' the attributes of the products). It is the pay-off for all the work and planning done so far.

Every time you approach a customer you should have only one objective – to achieve COS. The best way to achieve this goal is to ask a question, followed by a silence to force the client to break the silence and make a decision. Eye contact and body language are important at this point – look alert and attentive. If you attempt a closed question, you may get a flat 'No' – end of sale. A good closing question should be open-ended, such as:

- 'Where shall we deliver this to?'
- 'How far are you parked from the entry?'
- 'When shall we organise the delivery?'
- 'How do you want to handle payment?'

After-sales service

Selling is one thing, but inspiring a customer to come back and buy again is something else. A new customer is great but a regular customer is gold and should be looked after. This is where after-sales service comes in.

- Develop relationships with customers by keeping them advised of new products, specials and reduced prices, especially in areas they are interested in.
- Provide opportunities for valued customers to preview sale items, new products etc.
- Give discounts for big sales and invite customers to discounted workshops and lectures.
- Give away freebies and provide free delivery services to help increase customer goodwill.
- Operate a a free garden advice service to current and former customers. This can be used by retail and wholesale nurseries.
- Give a six-month to one-year guarantee on all your plant produce and six months of free advice. The small cost will pay off in the long term through customer satisfaction and positive word-of-mouth advertising. Lace this with a complimentary tea or coffee if customers are visiting the nursery.

Wholesale nurseries should have a plant list which is sent out to customers. Regular customers should be called to determine their stock supply, every 1–2 months. Keep a filing system where plant varieties, quantities bought and time of purchase can be easily accessed. Call valued customers and see if they need similar stock and quantities as last month/year. Introduce them to new products that are now ready. Do some homework with regard to plant popularity and keep up with consumer trends, so new plants will be good sellers. The key is to think for customers and to keep one step in front of them.

Questionnaires are an excellent way of finding out problem areas within a company. Use a comment box for written questionnaires, or phone customers to check satisfaction with plants, quality and service. Use the information constructively. Discuss improvements with dissatisfied customers and encourage continued custom by rectifying any problems. Give personal service, refunds, exchange products etc.

Newsletters, via post or email, are an excellent way to keep customers informed about what is happening in a business. They could cover new staff, staff profiles, new products, company policies, company changes/expansions etc. Use them as informative handouts rather than target marketing. Newsletters help make customers feel part of the 'family'.

Customer satisfaction should be the main aim in business. If good service is given before and after the sale then your advertising costs will decrease as word-of-mouth spreads. Happy customers come back. Advertising and promotions are always needed to retain present customers and gain new ones.

Market research

Market research attempts to make unknown things known, and involves all the activities which help management reach marketing decisions. Successful marketing depends upon knowing and understanding the people or groups you are marketing to, what they want and how they are likely to react to your product.

When you understand your marketplace, you can set realistic marketing goals and provide structures for reaching those goals. Assess the results of marketing efforts and modify your future marketing program accordingly.

Types of market research

Customer research
This involves determining the needs and wants of prospective customers, assessing the potential of specific market areas and studying the competition. Customer research also identifies demographic choices, such as:

- the geographical location you will market to – local, regional, national or global;
- the age and sex of the group you wish to target – children, teens, young adults, middle-aged, elderly or several of these groups;
- the social group you are targeting – families, singles, affluent, working-class, health-conscious etc.

Product research
This involves looking into new product development, testing prices to determine if they are too high or low and so on. For example, you should keep abreast of new Plant Variety Rights releases and their availability.

Promotions research
This means checking the effectiveness of promotions or advertising and comparing cost-effectiveness of different advertising types. Issues include:

- how it will be promoted – for example advertising, websites, partnership networks or distributors, press releases;
- how it will be distributed – for example through retail outlets, home-based business, wholesaler distributors, direct mail;
- how sales will be contracted – for example, payment plans, refund/returns policies, credit card facilities, establishing lines of credit.

Sales research
This involves evaluating staff sales techniques, looking at cost of selling, analysis of sales territory/distribution and so on. Cross-reference sales to advertising if possible; using brochures may help in this respect.

Company research
This involves determining industry trends, determining the company's image in the marketplace, studying employee morale, or location of facilities. How do locals see your nursery for professionalism and service? In any business, success is determined by a combination of many factors.

Market research in the nursery industry considers different things in different situations. Below are some factors that are usually researched:

- progressive or backward company policies;
- helpful and courteous staff;
- service speed and efficiency;
- good or poor after-sales service;
- the effectiveness of promotions and advertising;

- dispatch of plants;
- quality of plants on arrival.

Steps in market research

1. Define the problem. What information is required? For example, are you trying to determine how to increase sales by 10%, or are you assessing the best way to change the way you distribute your product?
2. Conduct an investigation. Examine past records which relate to the problem. Speak with people in the know, who might help with this problem. Try to find any relevant information which has been published, for example in trade magazines or by the Bureau of Statistics.
3. If more information is required, you may decide to take further action such as surveying existing or potential customers.
4. If the problem is still not clear, it may be necessary to employ a professional market research firm to handle it.

Gathering information

There are two categories of information for market research. Primary information is data not readily available and requiring a real effort to discover, whereas secondary information involves data that has already been compiled.

When collecting information for market research, always keep in mind the:

- reliability of your source;
- possibility of bias;
- date when the information was compiled;
- reason the information was gathered. Ensure the data is relevant to your business circumstances.

Primary data

Survey method: asking people what they think. It is relatively inexpensive and adaptable to a wide variety of situations. Questions are asked through personal interviews, or through the less-expensive techniques of mail questionnaires and telephone interviews. Personal interviews are the most accurate; mail and telephone surveys produce the quickest results.

Observation method: watching people and how they react to particular plants in flower, ornamental displays and so on. This can be done by making observations of customers at the point of sale and when exposed to demonstrations. Cameras or tape recorders can be used to record reactions, but their disadvantage is that observations may be misleading and inaccurate.

Experimental method: setting up a deliberate experiment. For example, put some plants of a particular specimen in one part of the nursery at one price, and similar plants in another part of the nursery at a different price and watch for the optimum balance to achieve good turnover and profit.

Secondary data
Sources might include:

- company records;
- government statistics;
- trade associations, institutes etc.;
- research organisations;
- trade or industry publications – there are numerous periodicals and journals related to the nursery industry.

Marketing budget

The four main ways of determining a marketing budget are the affordable, the percentage of sales, the competitive parity, and the objective and task methods.

Affordable method

The affordable method is based upon what the business can afford. Nurseries set a marketing budget according to available funds. Its major difficulty is a fluctuating advertising budget, making long-range planning very difficult.

Percentage of sales method

The percentage of sales method is based on percentage of current or anticipated sales (either based on % of each item sold or % of total dollars received). It bears a closer relationship to the movement of sales in the industry, and it encourages management to think in terms of relationships between advertising costs, prices and profit. It also encourages stability between competitors. Its disadvantage is that it discourages experimentation and depends on yearly fluctuations. This restricts long-range planning.

Competitive parity method

The competitive parity method is a budget that matches that of the competition. Its advantage is that it is based upon the collective wisdom of a particular sector of industry. On the other hand, there are no real reasons to believe that the opposition is more proficient than you!

Objective and task method

The objective and task method involves defining an objective to be achieved by advertising, then setting up an advertising program to meet that objective. This might be done via the following steps:

- establishing a market-share goal;
- determining the % of market share which needs to be reached;
- determining the % of potential customers who need to be convinced to do business;
- determining the number of advertising exposures needed to get to 1% of the population. For example, how many copies of the ad, how many times it is run on television or radio;

- determining the number of gross rating points which would need to be obtained for a radio, television or internet advertisement (A gross rating point is one exposure to 1% of the potential buying population);
- determining the advertising budget to achieve the purchase of one gross rating point.

Budgeting case study: GreenPlant Nursery

GreenPlant Nursery is a hypothetical nursery engaged in wholesale and retail plant sales, and allied service activities. At commencement, it employs three staff with one manager/owner. The business plan estimates that fifteen full- and part-time staff will be employed when all aspects of the business are fully operational.

Market identification and definition

The marketing plan is a three-stage process:

- wholesale production nursery;
- retail nursery;
- tourist facility.

Although the various activities of the project will share some common markets and marketing techniques, for the sake of simplicity this marketing plan is organised on the basis of each activity. The major markets covered include sectors of the wholesale and retail plant markets and the tourist industry.

Labour

At least 15–20% of labour should be devoted to marketing from the very start of the project. As office staff requirements will be relatively minor in the early stages of production, staff designated for these positions could be readily involved in marketing activities. Equipment used for marketing can also be used for other aspects of business operations.

Equipment

To conduct efficient marketing the business will need the following:

- a telephone system capable of taking up to four calls at a time;
- a fax – this is important for rapid communications with customers and suppliers. Many nurseries send their orders by this method. This should be purchased as soon as possible;
- a computer system with word-processor, accounting system, database and internet access. This can be used for keeping stocklists up-to-date, correspondence and billing;
- transport – something to transport plants in (e.g. a covered tandem trailer with racks, or large covered truck);
- external signs;
- business cards;

- promotional leaflets and perhaps catalogues;
- printed labels.

Plant production

With the need to develop staff's production skills, access to some 'temporary' markets will be necessary. That is, production should commence with easier, general nursery varieties.

Promoting the nursery

There are various ways of promoting a new business:

- through press releases;
- through paid advertising;
- through stands at shows;
- by phone or direct mail to potential customers;
- through catalogues/stocklists;
- through involvement in trade organisations or marketing service groups;
- on a website.

Selling plants

Plants may be sold any of the following ways:

- seeking advance orders for contract growing, for example through chainstores, growing-on nurseries or government departments;
- selling from stands at trade shows, agricultural shows and markets that both promote and make direct sales of plants;
- selling to people who visit the nursery site;
- selling through agents;
- receiving phone calls from and dealing with people who have heard of the nursery through promotional activities;
- repeat trade from previous customers and making direct contact with targeted customers, for example contacting herb nurseries to sell herbs or native nurseries to sell natives;
- putting plants into other outlets on a sale-or-return basis;
- by doing the rounds of nurseries for direct sales;
- mail order sales.

Processing wholesale orders

This involves routine jobs including:

- taking an order over the phone, by fax, by email, via post, or in person;
- getting the plants together for a delivery;
- labelling the plants;
- packaging;
- making deliveries.

Direct nursery sales from the site

This can be developed early in the nursery's life, but no earlier than six months from commencing propagation. Direct-to-public plant sales can commence well before the tourist market is targeted with promotion. Permits from council may be needed for direct sales.

Labour is an important issue. Staff must be available to serve customers whenever the retail area is open. Some of the initial stock can be potted into larger pots to sell direct to the public, for example in 100–125 mm (4–5") round pots. Pots this size are readily marketable to tourists.

Some signs and leaflets will also be needed (e.g. a sandwich board at the main road to direct traffic to the nursery), sales can be readily promoted through the local paper. The site should also display a concept plan showing future development.

The direct sales area should initially be small and well-maintained, and restrict public access to other areas.

Tourist-related activities

Once plant production and nursery sales are established, attention can be turned towards marketing to the tourist industry. At this point, the project will be able to offer the following to tourists:

- sale of plants produced in the nursery;
- tours of the nursery and grounds;
- display gardens perhaps containing a maze or picnic facilities, depending upon the way the grounds have been developed;
- other services to tourists, for example a service/shop area located adjacent to the office. This way, it is possible for the person who looks after the office (at slow times) to also attend to any visitors.

Developing the tourist market will require the use of regional publications and special-interest groups. Information, and perhaps some product sales, should also be available in regional tourist information centres, motels and other places visited by tourists in the area. Enquiries with the local Chamber of Commerce should help you to find such places and determine their best utilisation.

Marketing timetable

Stage 1

The first six months of nursery operations will concentrate upon the wholesale aspect of the nursery, developing plant production facilities. The following should be done.

- Advertise as a propagation nursery in trade magazines.
- Send out press releases every 6–8 weeks, initially as 'news items' telling how the project got started and how it is developing.
- Design, make up and print general promotional brochures.
- Compile stocklists of plants in production (on a word-processor or in a database).

- Direct-mail promotional leaflets, stocklists and covering letters to growing-on and retail nurseries, before plants are ready for sale.
- Make direct contact by phone and by visiting potential customers such as government departments and growing-on nurseries.
- Design and order a series of signs for use on-site, at markets and in shows.
- Join one or more trade organisations and become active in having a nursery representative attend seminars or meetings.

Stage 2

After nursery stock is beginning to increase and excess produce is becoming available for sale, you should do the following.

- Continue with the marketing activities started in stage 1.
- Obtain council permission and place signage on main roads and at the front of the property to direct people onto the property for direct sales.
- Commence advertising direct-to-public sales through general magazines.
- Commence selling at markets and promoting/selling through trade shows and exhibitions. Experiment with other avenues of marketing and develop marketing in the areas which are most successful.
- Establish a website.

Stage 3

Once nursery markets are being established and sufficient profitability and cash flow achieved, attention can be turned to developing and marketing the tourist side of the business.

- Advertising would be broadened and expanded to target the tourist industry. For example, a new website could be created or advertising inserted in the travel section of regional and national newspapers.
- Two separate promotional campaigns should be run, one targeting the people who buy plants from the wholesale nursery, the other targeting the tourist industry and general public. The results of each program should be monitored and adjustments made accordingly, on an annual basis.

The promotional mix

Whichever budgeting method is used, the marketing budget is always a finite amount. Therefore decisions have to be made regarding the proportion of resources allocated to a particular activity. For example, certain equipment such as a telephone is essential right from the start of operations, but a major expense such as creating a website can be postponed until the business is generating income and sufficient stock is being produced to justify the investment.

The marketing budget tends to be greater during the early stages of a business or when changes to the business, such as new products, have to be communicated to customers.

New equipment and extra labour have to be allocated sufficient funds if the marketing efforts are to be effective.

Although these activities are not always financed as part of the marketing budget, they are integral to the marketing process and must be coordinated with the marketing program:

- telephone;
- fax;
- computer system;
- delivery truck;
- external signs;
- business cards;
- promotional leaflets and catalogues;
- printed labels;
- plant containers.

An important aspect of marketing, particularly for the owner/operator, is participation in the broader nursery industry. As well as raising the profile of the business, it keeps the owner/operator informed of changes and opportunities. Time and resources have to be spent upon:

- trade shows;
- visits to customers;
- participation in trade organisations or marketing service groups.

Stage 1

At commencement, it is important to devote resources to:

- press releases;
- advertisements in industry journals;
- trade shows;
- mail order promotion;
- direct approaches to potential customers.

Stage 2

When the retail nursery is operational, marketing has to expand to support the following programs:

- on-site signage;
- carefully targeted magazine advertising;
- promotional displays;
- promotional activities for events such as spring sales and Mother's Day;
- website.

Stage 3

All effective marketing techniques should be continued throughout stage 3. The following should also be considered, with a particular emphasis upon tourists and tourist operators:

- television and radio advertising;
- newspaper advertising;
- promotional activities for the tourist market;
- an expanded website.

Legal implications of marketing

As with any business, both wholesale and retail nursery managers must consider the legal implications of their business operations. You are selling a product to consumers, who include the retail nursery, landscaper and retail customers. It is not a simple case of growing a plant and selling it. The customer has legal rights; so do you as the grower or retailer.

The content of consumer, business and contract law varies between jurisdictions and the following comments are intended only as a guide. Readers should contact the relevant government department in their state or territory for further details. Laws that govern the sale of goods in Australia include those discussed here.

Contract law

Contract law sets down guidelines by which people can enter binding agreements – in return for some 'advantage' they voluntarily enter into a stated 'obligation'. A contract is a legally binding promise and all contracts begin with a promise (but not all promises are contracts). It does not exist until the parties reach agreement on what is being given and what is to be accepted by each of the parties concerned.

Contract law set outs the rights and responsibilities of buyers and sellers. For example, everyone entering a contract has a 'duty of care' to the other parties to the contract. If one of the parties breaches the contract, the other parties can sue for restitution or damages.

As the sale of goods and services is a form of contract, contract law applies to the contracts of sale between a nursery business and its customers. In other words, nurseries that sell products and services are bound to fulfil their obligations whenever they offer goods for sale.

Commonwealth Trade Practices Act

This governs contracts between a business, a corporation and a consumer, and contracts which involve interstate trade. It is effective throughout Australia. The Act is diverse and controls many aspects of business activity, including:

- price-fixing;
- retail price maintenance;
- price discrimination;
- exclusive dealing;

- business mergers;
- lessening of competition and monopolisation;
- credit card use;
- overseas exports.

Consumer laws

There are a number of different Acts that provide consumer protection. These laws guarantee basic consumer rights:

- safety – the goods are safe to use;
- knowledge – the buyer has the right to have sufficient knowledge about the goods or services purchased. There should be sufficient knowledge to ensure consumer protection from physical harm, from damaging or misusing the goods purchased, to prevent the consumer from buying things which they do not need, and so on. Most nurseries provide extensive information on individual plants so customers know the conditions needed to grow that plant. They can ask for more information or make intelligent decisions using the information provided, regarding other secondary products such as fertiliser and soil;
- choice – the buyer has the right to choose which product they wish to purchase;
- complaints process – the buyer has the right to express any complaints. To minimise complaints, it is worthwhile conducting a survey or having a comments box. For example, wholesale nurseries might include a brief questionnaire when sending out their catalogue to regular customers.

Warranty and condition

Under law, a 'warranty' is a minor or non-essential term in a contract. A 'condition' is a major or essential term.

Most nurseries will warrant their stock is true to name and in healthy condition at the time of sale. Some nurseries will warranty their plants for 6–12 months; others will not be held responsible on transplantation of the stock.

Catalogues from wholesale nurseries often contain information regarding the lack of warranty on the description, productivity, viability, growth rate and mature size of the stock sold.

Advertising and promotion

It is illegal to make misleading or deceptive statements or actions in advertisements or promotional material.

Seller's liability

If the seller has breached the conditions of a contract, the buyer is normally entitled to rescind the contract, return the goods and receive a full refund, except in certain situations. For example, a buyer cannot reject goods just because the seller hasn't fulfilled all conditions of sale, unless there is a clause that allows it written into the contract.

Withholding goods is illegal after the title for goods has passed to the buyer. The buyer may sue the seller if goods are not supplied. As most customers do not normally pay for nursery stock until it is delivered, this is not normally a problem.

Manufacturer's liability

Normally, if there is a problem it must be dealt with between the parties involved in the contract. The purchaser will normally sue the seller. In turn, the seller may sue the manufacturer who supplied the faulty item. For a manufacturer to be held liable, it must be shown that:

- they owed the affected person (who is complaining) a duty of care;
- they breached that duty by failing to take care in manufacture;
- the lack of care by the manufacturer caused damages to the buyer.

Even though this is the normal case, courts have sometimes allowed the manufacturer to be sued by the consumer when a collateral contract is involved. This involves a situation where a retailer made a purchase from a manufacturer, based upon statements with which the manufacturer then did not comply.

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Appendix 1
Horticulture resources and contacts

Horticultural schools

The Australian Correspondence Schools

The Australian Correspondence Schools offers a wide range of horticulture courses, including nursery management, that can be studied by traditional correspondence, online, or by e-learning (CD).

These include short courses on propagation, cutting propagation, plant breeding, wholesale nursery management, garden centre management, nurseryhands course, nursery sales assistant, plant identification, practical horticulture, horticultural marketing, e-commerce, personnel management, bookkeeping, herbs, hydroponics, horticultural science, tissue culture, landscaping, agriculture, soil management, permaculture and organics, and environmental studies.

Longer courses are also available, most of them accredited by the International Accreditation and Recognition Council. These include Certificate in Horticulture (with streams in propagation, landscaping etc.), Advanced Certificate in Applied Management (Nursery), Royal Horticultural Society Diploma in Horticulture and Advanced Diploma in Horticulture (Nursery).

More study options

The best way to teach horticulture used to be face-to-face instruction, but many students find this neither convenient nor economically viable. Also, students from other institutions have said that horticulture lectures given to hundreds of students in large classrooms, and the difficulty of accessing teachers outside the classroom, are not necessarily the best way to learn.

To give students more choice in their education, ACS provides a diversity of learning modes, including computers, videos, DVDs, e-books, the internet and CDs. This enables the school to cater to students' real needs and learning styles. For instance, horticulture students can study online or by traditional correspondence; go online to view streamed video lectures; access websites with more photos and illustrations to increase their plant knowledge; and borrow videos showing essential horticultural procedures. As they progress, they can undertake convenient self-tests and receive automated immediate feedback; submit work by videotape, digital images or email; and communicate with skilled tutors by email, phone or fax as often as they wish.

Practical horticultural training is an integral part of the ACS model. Students can access a growing collection of coloured and labelled photos of plants online to increase their ability to identify plants. They can view videos on propagation, correct transplanting, hydroponic growing, making compost, pruning and so on. This allows students anywhere in the world to see experts carrying out essential horticultural tasks, again and again – the next best thing to a private lesson. Students from all over the world can also demonstrate and be assessed on their practical skills through videotapes or photographs.

For details, contact:
The Australian Correspondence Schools
PO Box 2092, Nerang MDC Qld 4211, Australia
Phone/fax: (07) 5530 4855
Email: admin@acs.edu.au
Web: www.acs.edu.au

ACS Distance Education

ACS Distance Education is a UK-based school that is internationally recognised by the International Accreditation and Recognition Council. It runs a large number of horticultural programs, including courses that prepare students to sit examinations held by the Royal Horticultural Society, the UK's most prestigious horticultural body.

Students can study by correspondence or online learning. Courses on offer cover general horticulture, permaculture and organic gardening, amenity horticulture, production horticulture, nursery management, specialist plant courses and a range of environmental courses.

For details, contact:
ACS Distance Education
PO Box 236, Wallingford OX10 OWJ, UK
Email: admin@acsedu.co.uk
Web: www.acsedu.co.uk

Warnborough University

Warnborough University in the UK runs a number of degree courses by distance education. These include a Bachelor of Science with a major in Horticulture, and postgraduate studies. Warnborough University is internationally recognised by the International Accreditation and Recognition Council.

For details, contact:
Warnborough University

Warnborough House, 8 Vernon Place, Canterbury CT1 3WH, UK
Web: www.warnborough.edu

Royal Horticultural Society

The Royal Horticultural Society in the UK is arguably the largest horticultural organisation in the world, with a prestigious international reputation. It conducts a series of shows including the world-renowned Chelsea Flower Show. It has around a quarter of a million members worldwide who enjoy various RHS services, and also runs botanical gardens, research and advisory facilities, publishing services and bookshops.

RHS qualifications

The RHS is a nationally accredited awarding body in the UK and has offered examinations in horticulture for over a hundred years, providing nationally recognised qualifications for both professional horticulturists and dedicated amateurs. Exams may be taken twice annually at the following levels: General Certificate, Advanced Certificate, Diploma and Master. Apply to the RHS to take an exam.

Anyone can apply for and sit exams without having undertaken a course of study, though they might need to study in preparation then apply to take the exam. Suitable study courses are offered by the Australian Correspondence Schools and other approved institutions. The RHS assesses the exams and awards the qualifications. Some qualifications require a practical exam which can only be taken in the UK.

For details, contact:
Royal Horticultural Society
Administrative Offices, Lindley Library and Exhibition Halls
80 Vincent Square, London SW1P 2PE, UK
Web: www.rhs.org.uk

Horticultural literature

Books

Ball, G., Ball RedBook, *Greenhouse Growing*, Reston Publishing, Virginia, 1985.
Berninger, L., *Profitable Garden Centre Management*, Reston Publishing, Virginia, 1978.
Browse, P., *The Commercial Production of Climbing Plants*, Grower Books, UK, 1981.
Davidson et al., *Nursery Management: Administration and Culture*, Prentice Hall, New Jersery, 1988.
Fenton, M. & J., *The Seed Savers Handbook*, Seed Savers Network, Australia, 1993.
Handreck, K. and Black, N., *Growing Media for Ornamental Plants and Turf*, University of New South Wales Press, Sydney, 1984.
Hartmann, H.T., Flocker, W.J. and Kofranek, A.M., *Plant Science: Growth, Development and Utilization of Cultivated Plants,* 7th edn, Prentice Hall, New Jersey, 2002.
Hartmann, H. et al., *Plant Propagation: Principles and Practices,* 3rd edn, Prentice Hall, New Jersey, 2002.
Horst, R.K., *Westcott's Plant Disease Handbook*, Van Nostrand Reinhold, USA, 1979.
Joiner, J., *Foliage Plant Production*, Prentice Hall, New Jersey, 1981.
Kelly and Bowbrick, *Nursery Stock Manual*, Grower Books, UK, 1985.
Macdonald, B., *Practical Woody Plant Propagation for Nursery Growers*, Timber Press, Oregon, USA, 1986.
Mason, J., *Starting A Nursery or Herb Farm*, Night Owl Publishers, Australia, 1983.
Mason, J., *Growing Ferns,* Kangaroo Press, Australia, 1990.

Mason, J., *Commercial Hydroponics*, Kangaroo Press, Australia, 1990.
Mason, J., *Growing Herbs*, Kangaroo Press, Australia, 1993.
Mason, J., *Propagating from Cuttings*, Kangaroo Press, Australia, 2002.
Mason, J., *Sustainable Agriculture,* 2nd edn, Landlinks Press, Australia, 2003.
Nelson, P., *Greenhouse Operation and Management*, Prentice Hall, New Jersey, 1991.
Sullivan, G., Robertson, J. and Staby, G., *Management for Retail Florists: With Applications to Nurseries and Garden Centers*, W.H. Freeman, New York, 1980.

Trade publications

The following is only a small selection of the hundreds of relevant trade publications available for nursery managers.

American Nurseryman, 223 W. Jackson Blvd, Suite 500, Chicago IL 60606, USA.
Australian Horticulture and HortiGuide, Rural Press, PO Box 254, Moonee Ponds Vic. 3039, Australia.
Commercial Horticulture, PO Box 26, 269 Epsom, Auckland, NZ
Garden Magazine, Royal Horticultural Society, 4th floor, Churchgate, New Road, Peterborough PE1 1TT, UK.
Greenworld, Glenvale Publications, PO Box 50, Glen Waverley Vic. 3149, Australia.
Grower Magazine, 50 Doughty St, London WC1N 2BR, UK.
Grower Talks Magazine, Ball Publishing, 335 N. River Street, PO Box 9, Batavia IL 60510-0009, USA.
International Plant Propagators Society Combined Proceedings (an annual collection of papers presented at conferences in different countries). Contact:
Australian Secretariat: Ms Pam Berryman, 27 Petunia Crescent, Mt Cotton Qld 4165, Australia.
Centre for Urban Horticulture, University of Washington, GF-15, Seattle, Washington 98195, USA.
UK Secretary: 2 Crondall Lane, Farnham, Surrey GU9 7BQ, UK.

Associations and societies

The following short list provides useful contacts that can refer you to organisations relevant to your needs and interests.

American Association of Nurserymen, 1250 1 Street, NW Suite 500, Washington DC 20005, USA.
Australian Institute of Horticulture, Unit 1c, 260 Manns Rd, West Gosford NSW 2250, Australia.
Garden Centre Association (UK), 30 Carey St, Reading Berkshire RG1 7JS, UK.
Garden Centres Association of Australia, PO Box 1056, Hartwell Vic. 3124, Australia.
Institute of Horticulture, 14/15 Belgrave Square, London,SW1X 8PS, UK, www.horticulture.org.uk
International Plant Propagators Society: Centre for Urban Horticulture, University of Washington, GF-15, Seattle,Washington 98195, USA; Mrs K. Frances Biggs, PO Box 124, North Richmond NSW 2754, Australia; Mrs Janette Gaggini, Mears Ashby Nurseries Ltd, Glebe House, Glebe Rd, Mears Ashby Northampton NN6 ODL, UK.
International Society for Horticultural Science, PO Box 500, 3001 Leuven 1, Belgium.
Nursery and Garden Industry Association of New Zealand, PO Box 3443, Wellington NZ.
Nursery and Garden Industry Australia, Suite 402/16–18 Cambridge Street, Epping NSW 2121; PO Box 907, Epping NSW 2121.
Royal Horticultural Society (UK), 80 Vincent Square, London SW1P 2PE, UK.
Seed Industry Association of Australia, PO Box 285, Drummoyne NSW 2047.

Internet sites

The following internet sites can be useful resources for people involved in the nursery industry.

www.acsedu.com\library – Online library developed by the author of this book and his staff.
www.acsGarden.com – A free global gardening e-zine with an extensive plant directory, horticultural product reviews and new articles every month.
www.horticulture.org.uk – Institute of Horticulture, a UK-based but globally focused professional body.

www.mantistech.com.au/ – Mantis Technologies, website developers who actually understand the nursery industry and plant naming.

www.mediaspread.com.au – An excellent resource for anyone needing media information about new products in the horticultural industry.

www.ngia.com.au – Nursery and Garden Industry Association of Australia.

www.thecareersguide.com – Free careers and employment information, including a free employment service that matches employers' needs with job seekers.

Australian seed suppliers

Arthur Yates & Co., PO Box 6672 Silverwater BC NSW 2141. Ph: (02) 9763 9200 (wide range of varieties, including flowers, perennials and cut flowers).

Australian Seed Company, PO Box 67, Hazelwood NSW 2779. Ph: (02) 4758 6132 (native tree and shrub seeds for landcare, revegetation).

Diggers Seeds, 105 Latrobe Parade, Dromana Vic. 3936 (wide range of vegetable, flower and perennial seeds).

D. Orriell – Seed Exporters, 45 Frape Ave, Mt Yokine WA 6060. Ph: (08) 9344 2290 (large range of native and exotic seeds, including palms, cycads, everlastings, Proteaceae, Australian and South African).

Eden Seeds, MS 316 Gympie Qld 4570 (non-hybrid flower, perennial and shrub seeds).

Ellison Horticultural, PO Box 365, Nowra NSW 2541. Ph: (02) 4421 4255 (extensive range of tree, shrub and palm seed).

Erica Vale Seeds, PO Box 50, Jannali NSW 2226 (wide range of seeds, particularly flower and vegetable).

Goodmans Seeds, PO Box 91, Bairnsdale Vic. 3875. (wide variety of flower and vegetable seeds).

Harper Seed Co., Ranford St, Albany WA 6330.

Henderson Seed Co., PO Box 118, Bulleen Vic. 3105. Ph: (03) 9850 2266 (vegetables).

HG Kershaw Seeds, The Parade, Dee Why NSW 2099. Ph: (02) 9984 7226 (wide range of native and exotic trees, shrubs and flowers).

Jerd Seeds, 140 Madden Ave, Mildura Vic. 3500; also 1 Orchid Court, Park Orchards Vic. 3114.

Jodi Seeds, PO Box 288, Cleveland Qld 4163 (Australian natives).

Kimseed Environmental, Osborne Park WA 6916. Ph: (08) 9446 4377 (native seed).

Kings Herb Seeds, PO Box 975, Penrith NSW 2751. (wide variety of herb, vegetable and flower varieties).

New Gippsland Seed Farm, Queens Rd, Silvan Vic. 3795. Ph: (03) 9737 9560 (herb and vegetable seed).

Nindethana Seed Service, RMB 939, Woogenilup WA 6324 (largest selection of native seed in Australia, including many rare and unusual lines. Suppliers of bulk seeds for rehabilitation work).

Northrup King Seeds, PO Box 335, Dandenong Vic. 3175 (wide range, including flowers, vegetables and perennials).

Q-Hort, PO Box 595, Cleveland Qld 4163.

Specialty Seeds, Hawthorn Park, Chanters Lane, Tylden Vic. 3444.

Vaughans Wildflower Seeds, c/- PO Gingin WA 6503. Ph: (095) 75 7551 (wide range of Australian native species, in particular Western Australian. Catalogue available on request).

W&G Plants and Palm Seeds, 216 Outlook Drive, Dandenong North Vic. 3175. Ph: (03) 9795 7505.

Walz Seeds Australia, PO Box 5579, Gold Coast MC Qld 4127.

West Australian Wildflower Seed Co., 11 Bertram Rd, Darlington WA 6070 (wide variety of Western Australian natives in packages or larger amounts).

International seed merchants

Abundant Life Seed Foundation, PO Box 772, Port Townsend WA 98368, USA.

Applewood Seed Company, 5380 Vivian St, Arvada CO 81067, USA.

Breeders Seeds, 17 Summerwood Lane, Halsall Ormskirk Lancs L39 8RQ, UK. Ph: (0704) 840775.

Chiltern Seeds, Bortree Stile, Ulverston, Cumbria LA12 7PB, UK.
Clyde Robin Seed Company, PO Box 2366, Castro Valley CA 94546, USA.
Colegrave Seeds Ltd, West Adderbury, Banbury Oxon OX173EY, UK. Ph: (0295) 810632.
Country Garden, Route 2, Box 455A, Crivitz WI 54114, USA.
D.V. Burrell Seed Growers Co., PO Box 150, 405 N. Main, Rocky Ford CO 81067, USA.
Earl May Seed & Nursery Co., Shenandoah IA 516032, USA.
Far North Gardens & International Growers Exchange, PO Box 52248, Livonia MI 48152, USA.
Gurney Seed & Nursery Co., Yankton Sd 57079, USA.
Hamer Flower Seeds, Sheraton House, Office 29, Castle Park Cambridge CB3 0AX, UK. Ph: (0223) 327520.
Harris Seeds, 3670 Buffalo Rd, Rochester NY 14624, USA.
Kings Herb Seeds (NZ), PO Box 19-084, Avondale, Auckland, NZ. Ph: (09) 887 588.
Nichol's Herbs and Rare Seeds, 1190 N. Pacific Highway, Albany OR 97321, USA.
Plants of the Southwest, 1812 Second St, Sante Fe NM 87501, USA.
Silverhill Seeds, 8 Silverhill Crescent, Kenilworth 7700, South Africa. Ph: (21) 762 4245.
Stokes Seeds Inc., Box 548, Buffalo NY 14240, USA.
W. Atlee Burpee Co., Warminster PA 18974, USA.

Nursery equipment

This includes heating, misting and greenhouses.

Advanced Environmental Structures, PO Box 592, Springwood NSW 2777. Ph: (02) 9833 2678.
Azrom Greenhouses – Israel, 'Pine Vale', Binya NSW 2665. Ph: (02) 6968 3251.
Clearpac, 4 Rocco Dve, Scoresby Vic. 3179. Ph: 03 9764 8255.
Geoff Miller Pty Ltd, PO Box 59, Highett Vic. 3190. Ph: (03) 5957 0777.
Harford Greenhouse, 18 Dandenong-Hastings Rd, Tyabb Vic. 3913.
Hortraco Pty Ltd, 12b/8 Gladstone Rd, Castle Hill NSW 2154. Ph: (02) 9899 3232.
Jeffery Electronics, PO Box 5003, Greenwich NSW 2065. Ph: (02) 9439 5982.
Kerst Horticultural Products, 45 Maraline Rd, Skye Vic. 3977. Ph: (03) 9782 2697.
Kroll Heaters, PO Box 1407, Orange NSW 2800. Ph: 1800 805 243.
Monbulk Rural Enterprises, Lot 2A Old Emerald Rd, Monbulk Vic. 3793. Ph: (03) 9756 6355.
Premier Nurseries, PO Box 882, Park Ridge Qld 4125. Ph: (07) 3803 0444.
Sage Horticultural, 121 Herald St, Cheltenham Vic. 3192. Ph: (03) 9553 3777.
Transplant Systems Pty Ltd, PO Box 295, Berwick Vic. 3806. Ph: (03) 9769 9733.

Appendix 2
Metric/imperial conversion

Area

Metric to imperial

1 square centimetre	= 0.155 sq inch
	= 100 sq millimetres
1 square metre	= 1.196 sq yards
	= 10 000 sq centimetres
1 hectare	= 2.471 acres
	= 10 000 sq metres
1 square kilometre	= 247.1 acres
	= 1 000 000 sq metres

Imperial to metric

1 square inch	= 6.452 sq centimetres
	= 1/144 sq foot
1 square foot	= 929 sq centimetres
	= 0.0929 sq metre
1 square yard	= 0.8361 sq metres
	= 9 sq feet
1 acre	= 0.4047 hectare
	= 4046.87 sq metres
	= 4860 sq yards

Length

Metric to imperial

1 millimetre	= 0.001 metres
1 centimetre	= 0.3937 inches
	= 10 millimetres
	= 0.01 metres
1 metre	= 3.281 feet
	= 1000 millimetres
	= 100 centimetres

Imperial to metric

1 inch	= 25.4 millimetres
	= 2.54 centimetres
1 foot	= 30.48 centimetres
	= 0.3048 metre
	= 12 inches
1 yard	= 0.9144 metre
	= 3 feet

Glossary

Allele One of two or more different expressions of a gene on a chromosome, e.g. a gene for flower colour may have two alleles, one for red and one for white flowers.

Anti transpirants Waxy materials sprayed over cuttings to stop the leaves drying out before the cutting starts to form roots. Also used to reduce water stress during transplanting and to prevent frost damage.

Backcross The crossing of a hybrid with one of its parents or with a genetically equivalent organism.

Bare-rooted plants Plants that have been 'lifted' from their growing area without soil or growing media left around their roots. This is common for many deciduous ornamental trees (e.g. elms, ashes, maples) and fruit trees (e.g. apricot, apple, peach, pear), and shrubs such as roses. The plants should be planted as soon as possible to prevent the roots drying out. They can be temporarily stored if the roots are covered with a moist material such as peat moss, straw or rotted sawdust.

Bedding plants Plants used for temporary displays, generally planted out in warmer seasons (e.g. many annuals).

Biocontrol Pest management technique that uses biologically derived agents such as bacteria, insects or animals to control pests, diseases and weeds.

Bottom heat This is where heat is applied at or near the base of plants to stimulate growth. This can be done in a variety of ways, including under-bench heating with heat cables or hot water pipes, heating of floors in greenhouses using heat cables, or composting materials such as sawdust or manures. See also **Hotbed**.

Bud sport A mutation that arises in a bud and produces a genetically different shoot. It occurs in asexually propagated plants and is characterised by the plant having the same genetic makeup in all its tissues.

Capillary irrigation Sub-irrigation system where water soaks up into the bottom of plant pots or trays, usually through capillary mats or sand beds. The plants receive a constant supply of water, without wetting the foliage.

Carbon dioxide enrichment Addition of carbon dioxide inside greenhouses to accelerate plant growth. Combustion heaters or bottled gas are used to add the CO_2 to the greenhouse.

Chemigation Application of chemicals through the irrigation process.

Chimera A plant with a chimera has two or more genetically different tissues, as a result of a genetic mutation.

Coldframe This is in effect a mini-greenhouse. Generally unheated, they are commonly used to provide protection for plants being propagated, or for plants that may need a short period of protection against extremes of climate. They have the advantage of being easy to move and to construct.

Container plants Plants grown and sold in containers, as distinct from in-ground production. Nursery containers are most commonly rigid plastic pots, but plastic bags are sometimes used.

Cultivar A genetically distinct variety of plant, usually the result of a breeding program.

Cutting A cutting is a piece of root, stem or leaf which has been treated in a way that stimulates it to grow its own roots, stems and leaves, hence producing another new plant. The new plant is a clone of the parent plant, i.e. it has the same genetic characteristics. Cuttings are the most widely used method of propagating shrubs, foliage plants and herbaceous plants.

Demand irrigation A watering system that uses a sensor or probe to measure the moisture level of the soil. The sensor is linked to a receiver that automatically triggers the irrigation solenoid.

Dibble stick A short pencil-like stick used to make holes in growing media for the potting-up ('pricking out') of seedlings, or for inserting or potting-up cuttings.

Dihybrid cross Crosses between individuals that involve two traits.

Division Method of dividing perennial plants which form a crown.

F1 hybrid First-generation hybrid resulting from crossing two varieties.

Fertigation Application of fertilisers through the irrigation process.

Field capacity Point at which the soil is holding as much water as it can without excess water draining away and being lost.

Flats Shallow trays with drainage holes in the bottom, commonly used for germinating seeds or rooting cuttings.

Forcing The use of heat and altered light conditions to induce very early flowering or very tall growth. Commonly used in cut flower production.

Gamete Sex cell or reproductive cell. The female gamete is the ovum and the male gamete is the pollen.

Garden centres Retail outlets that sell a variety of plants, garden supplies and landscaping products to the public.

Gene The unit of heredity on a chromosome. Each gene normally controls a single trait (heredity character).

Genetics The study of inheritance.

Genotype Genetic make-up of a plant.

Germplasm The protoplasm of the sexual reproductive cells containing the units of heredity (chromosomes and genes).

Grafting A form of vegetative propagation where a bud or section of plant stem (the scion) is inserted into another plant (the rootstock). The cambium layers of both scion and rootstock must be in close contact for the union of the two plants to take place. Once the graft takes, the scion develops the same foliage, flowers and fruit as the plant it came from, while the rootstock supplies water and nutrients and controls the vigour and growth of the grafted plant.

Greenlife Plants sold in retail outlets; a term used to distinguish plants from other products sold by retailers.

Growing media Any material in which plants are being grown can be classified as a growing media. This includes soil, soil-less potting mixes, rockwool, vermiculite, even water (hydroponics).

Growing-on The process of raising young plants to a saleable size.

Growing-on nurseries Nurseries that specialise in growing-on seedlings or small plants to a saleable size. Growing-on nurseries buy bulk quantities of small plants from propagators, grow them on for a period, then resell them to landscapers and retailers.

Hardening-off Gradual exposure of young or tender plants raised in protected environments, such as greenhouses, to outdoor conditions.

Herbicide A chemical that kills plants; used to control weeds. Also called weedicides.

Heterosis Hybrid vigour; the superiority of the hybrid over its parents in any measurable character.

Hormone treatments Powders, gels or liquids containing growth hormones, widely used in cutting propagation to promote rooting. Other hormone treatments are used to control a variety of growth processes including flowering, fruiting, germination, dormancy and branch development.

Hotbed This is a bed used for plant propagation that provides heat to the base of seed trays or to pots of cuttings to stimulate germination in seedlings and subsequent root growth, and root initiation and growth in cuttings. Heat is normally supplied from hot water pipes or from resistance cables which heat up when an electric current is passed through them. The heating elements generally have some material such as propagating sand, vermiculite, gravel or perlite placed around them to help spread (diffuse) the heat.

Hybrid An individual which results from interbreeding two different plants or two different populations of plants. An F1 plant is a hybrid plant.

Inbred line A group of naturally cross-fertilising plants maintained as self-fertilising lines through artificial prevention of cross-pollination. Generally used to produce hybrid cultivars.

In-ground production Plants grown directly in the ground, as distinct from containers.

Juvenility The stage of a plant's life following the germination of a seed to produce a seedling. Vegetative growth dominates, and juvenile plants can't respond to flower-inducing stimuli. In some plants juvenile foliage differs markedly from adult foliage (e.g. some eucalypts). In difficult-to-root plants, taking cutting material from stock plants in a juvenile phase will often give better results than using older (adult growth phase) material.

Layering A form of vegetative propagation where roots are produced on an intact stem connected to the parent plant.

Line cultivar A group of self-fertilising plants that naturally maintains their genetic identity from generation to generation.

Linkage The tendency for certain genes to be inherited together, due to their proximity on a chromosome.

Living colour Plants cultivated to provide colourful displays (i.e. foliage, flowers, fruit). These can be in-ground or in containers, and be grown for short- or long-term display.

Micro-irrigation Irrigation system that uses micro-sprays or drippers to deliver water slowly and frequently to the plant root zone. The basic components of micro-irrigation systems include an automatic controlling device, a pressure regulator to ensure water pressure is even between drippers, system filters, control valves and drippers or micro-sprays. The system uses less water and delivers it more efficiently to plants, and reduces weed and disease problems.

Micro-propagation This is the production (propagation) of plants from very small plant parts, tissues or cells. They are grown under aseptic conditions in a highly controlled environment. The term 'tissue culture' is a collective term used to describe a number of in vitro procedures used in culturing plant tissue, including producing haploid plant cells and artificial hybridisation.

Monohybrid A plant resulting from the crossing of two parent plants, each from a pure (or true-breeding) line. The parents differ at one gene (locus) that influences a single character (trait) and are homozygous for different alleles of the gene.

NPK The three main elements required for plant growth: Nitrogen (N), phosphorus (P) and potassium (K). Fertilisers containing these elements are sometimes called 'complete fertilisers'.

Patents In the plant-breeding industry, patents are used to protect a process or the components of a variety, e.g. a technique of gene sequence.

pH A measure of the acidity or alkalinity of a solution. pH is measured on a scale of 0 to 14, with 7 being neutral, below 7 acid and above 7 alkaline. Most plants prefer a soil pH of 6–6.5 (slightly acid) but there are many exceptions. Soil pH or growing media may be raised with the addition of lime or dolomite, and lowered with the addition of sulfur.

Plant breeders' rights (PBR) Exclusive commercial and legal rights to a registered plant variety. The owner of the registered variety may be the original breeder or a licence holder to whom the breeder sold the rights to grow and sell the plant. To be eligible for PBR, the variety has to meet strict criteria of distinctiveness, uniformity and stability (DUS), and it must be 'new' and have a recognised breeder or discoverer.

Plugs These are individual plants, or small clumps of plants, grown in trays containing large numbers of individual cells. For example, the tray may be 18 × 32 cells, making a total 576 cells per tray, with each individual cell measuring 20 × 20 mm (0.75") with a depth of 30 mm (1.25"). Each cell has an individual drainage hole. The trays are filled with a growing media and seed is planted into each cell, either by hand (very slow) or by machine. There are machines that can plant individual seeds into each cell, very quickly. The trays are made of plastic that has some degree of flexibility, so that it can be bent a little to allow easy removal of individual plugs (rootball and growing media combined). This type of growing system is ideal for flower and vegetable seedlings, and can be highly mechanised (e.g. filling trays with soil, seeding, potting-up individual plugs).

Potted colour Plants grown in containers to provide a colourful display. They are commonly used as an alternative to cut flowers (e.g. chrysanthemums in 150 mm/6" pots), and are generally discarded once their peak display (e.g. flowering) has finished.

Potting-up The process of moving plants from a small container to a larger container that holds more soil and water, allowing for plant growth and development.

Pricking-out The transfer of seedlings from pots or trays into larger containers.

Production nurseries Nurseries that specialise in propagating plants, which are then sold to retail outlets or growing-on nurseries. Often termed 'wholesale nurseries'.

Propagation Multiplying a single plant into two or more plants. Propagation is the basis of nursery production – raising quantities of new plants for commercial and domestic horticulture. There are two main methods of propagation: asexual and sexual propagation. See **Vegetative propagation** and **Sexual propagation**.

Provenance This is also known as 'seed origin' and refers to where the seed has been produced. This can give an indication of the genetic characteristics of the seed (e.g. size, shape, flower colour, adaptation to climatic conditions, resistance to pests and diseases, tolerance to different soil conditions).

Pulse-watering Watering system that use short but frequent periods of irrigation, resulting in better water penetration and less wastage through runoff.

Purebred line Homozygous strain, obtained by successive self-fertilisations.

Recessive allele The allele which is not expressed in the presence of another allele for the same trait. For example, if red flower colour were dominant and white flower colour were recessive, a cross between a red- and a white-flowered plant would produce only red-flowered plants in the F1 generation.

Roguing Removal of undesirable individuals to purify breeding stock.

Rootbound Matted circling roots that develop when a plant becomes too large for its container. The problem may still occur after the plant is transferred to a larger container or into the ground, resulting in poor growth and lack of stability.

Rootstock The stem or trunk into which a bud or stem is inserted during grafting; the lower part of a grafted plant. Also called the 'understock'.

Runners Shoots that grow along the ground from axillary buds and produce roots at the nodes, e.g. strawberries.

Scarification Any process that breaks, scratches, cuts, mechanically alters or softens seed coats to make them more permeable to water and gases. Techniques include dipping in hot water, dipping in concentrated sulfuric acid, removing hard seed coats with sandpaper, and nicking seed coats with a sharp knife.

Segregating populations Populations of plants which are not uniform, i.e. different plants within the population possess different combinations of alleles.

Selection The process of choosing individuals from the population that will be used for breeding.

Sexual propagation Commonly called seed propagation, plants are grown from a seed or spore which has been produced by fertilisation of the female part of a plant by the male part. A sexually propagated plant is not always exactly the same as the plant from which the seed or spores were taken because it contains the genetic characteristics of both parents. Used to propagate most flowering annuals, biennials, vegetables, ferns and some trees and shrubs.

Slow-release fertiliser Fertiliser that releases its nutrients over a period of weeks or months, depending on its formulation, the temperature and/or moisture. Widely used to fertilise plants in nurseries.

Soil ameliorants Additives used to improve soil characteristics. Examples of commonly used ameliorants are compost (to increase the organic matter in soil) and lime (to raise the soil pH).

Standards Plants grown-on as a single tall stem (e.g. some fruit trees and roses). Some prostrate cultivars are also budded or grafted onto taller-stemmed rootstocks to create pendulous forms (e.g. weeping elm, *Grevillea gaudi-chaudi* and *Grevillea* Royal Mantle).

Stock plants Parent plants from which cutting propagation material is obtained. There are three main sources of stock plant material: plants growing in parks, around houses, in the wild, etc.; prunings or trimmings from young nursery plants; and plants grown specifically as a source of cutting material. Stock plants should be correctly identified (and true to type), and in a healthy condition.

Stratification This is where dormant seeds, that have imbibed water, are subjected to a period of chilling to 'after-ripen' the embryo. This process is also known as 'moist-chilling'. Dry seeds should be soaked in water prior to stratification. Seeds are then usually mixed with some sort of moisture-retaining material, such as coarse washed sand, peat or sphagnum moss, or vermiculite. The material should be moistioned prior to mixing. The mix is stored at a temperature of 0–10°C (32–50°F). The lower shelf of a domestic refridgerator is usually suitable. The period of stratification depends on seed type, but is usually 1–4 months. In areas with cool winters, stratification can be carried out in beds outdoors, but seeds should be protected from pests such as birds and mice.

Suckers Shoots that develop from the root of the parent plant. Suckers can be divided when they have developed independent root systems (e.g. raspberries).

Systemic Used to describe chemicals that are absorbed into the plant's sap stream and distributed to all plant parts.

Thermal screen Screen fitted into the roof panels of greenhouses to control the amount of UV light entering the greenhouse. Computer-controlled environmental systems are used to extend the screens whenever light exceeds a pre-set level.

Tissue culture See **Micro-propagation.**

Topiary A plant that has been trained and shaped into a recognisable form, such as a standard, spiral or animal shape.

Transplanting Removing plants from a container or garden bed and planting into another (usually larger) container or garden bed. Most commonly plants in production nurseries are propagated in plugs, trays and tubes, then transplanted into larger containers which hold a greater quantity of growing media, allowing for root development and plant growth.

Tubes Small narrow containers, commonly used for the first potting-up stage of newly propagated seed or cuttings. The tube-like nature encourages new roots to grow straight down, reducing the risk of roots coiling. The most common tube used in Australia has an upper diameter of 50 mm (2") and a depth of around 70 mm (3"), tapering to a lower diameter of about 40 mm (1.5"). This type is most widely used in producing stock for planting-up into larger containers. Deeper tubes are also commonly used for tubing-up quick-growing seedlings that are to be used in large-scale plantings (e.g. reforestation, farms, trees). Some nurseries specialise in tubestock production for sale to other nurseries, for growing-on.

Tubestock Plants grown in tube-like containers. See **Tubes**.

Vegetative propagation Producing a new plant from only one parent, using a plant part such as a piece of stem, leaf or root. The parent plant and offspring are genetically identical. Also called asexual or clonal propagation.

Viability The storage life of ungerminated seed.

Wholesale nurseries Nurseries that grow plants and sell them to retail outlets or landscapers in bulk quantities. See **Production nurseries.**

Wilting point The moisture content of soil at which plants wilt and do not recover. Also called 'permanent wilting point'.

Wounding Root production on cuttings can be promoted by wounding the base of cuttings. A common method of wounding plants is to cut away a thin strip of bark, 15–30 mm (0.5–1.25") long (depending on the size of the cutting) from each side of the cutting near the base. The strip should not be cut too deeply, just enough to expose the cambium layer (the soft layer of new growth between the wood and the bark), without cutting very deeply into the wood beneath.

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