Integrated pest management in ornamentals information kit

Reprint – information current in 2000

REPRINT INFORMATION – PLEASE READ!

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This publication has been reprinted as a digital book without any changes to the content published in 2000. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 2000. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in ornamental horticulture. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

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Queensland Government

Preparing for IPM property & staff

What can you expect to learn from this section?

How to prepare your property for IPM. Before contemplating monitoring for pests and diseases or managing them, you need to consider what you can do to minimise the risk of pest and disease occurrence in the first place. Advice on management, and physical, cultural and chemical considerations will make you better prepared to practise IPM. Adapt it to suit your property.

Refer to Handy Guide 1, IPM Checklist *after reading this section and when designing an IPM program on your property.*

If you would like more information on preparing for IPM, read Best Practice Guidelines from the Nursery Industry Accreditation Scheme, Australia (NIASA). These can be obtained from the nursery industry association in your State (see Section 9, Directory, *page 2) or through the Nursery Industry Association of Australia's web site: www.niaa.org.au/*

This information guide is also the resource document for the nationally accredited IPM training course. In this course you will receive thorough instruction on developing the skills and understanding necessary to have a successful IPM program on your property.

Contents

Preparing for IPM

Let's assume you have made the decision to implement IPM on your property. For the beginner, starting is the hard part. IPM may seem daunting at first, but it may help to remember that Rome wasn't built in a day. Good IPM requires forward planning and thinking through the available options. Every property is different, and will have different requirements and capabilities.

John Bunker, from Redlands Nursery in Queensland, says:

"Anyone wanting to try IPM should start on a small scale first. Read as much as you can about IPM and give it a go. Run a trial to find out what works for you. Record keeping is vital. This is certainly the safest way to approach IPM. IPM is achievable, sustainable and is going to be the way of the future."

An IPM program can be divided into two parts; the first is covered in this section and the other in *Section 4, Preparing for IPM: monitoring and decision making.* In this section we consider the all-important roles and attitudes of management and staff, physical and cultural considerations for the site, and management of chemicals. See also *Handy Guide 1, IPM Checklist*.

A hygienically maintained greenhouse

Management considerations

Ornamental plant production is a business and IPM should be seen as an integral part of that business. The Nursery Industry Accreditation Scheme, Australia (NIASA) advocates IPM practices in its Best Practice Guidelines. IPM is not a fad; done properly, its guiding principles are common sense.

The success or failure of any IPM program will depend on how it is managed. If you are a manager, here are some of the questions you might like to consider in relation to IPM.

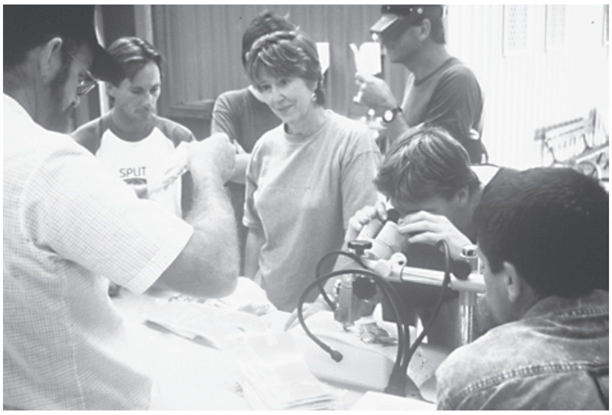
- **Are you committed to IPM?** If you aren't committed to IPM, there is a strong likelihood that your staff will not be either. IPM requires a team approach, with both staff and management pulling in the same direction.
- **Are your staff supporting you?** If all your staff members aren't supporting you, there are inevitably going to be mistakes. Even a small mistake can have major consequences. Did someone forget to sterilise a cutting knife before taking cuttings and spread diseases. Did someone end a well-established biocontrol program because they thought they might as well use up the mixture left in the spray tank from another job? Your staff are your greatest asset. You need their willing cooperation and they need to be informed about IPM.
- **Do you shoot from the hip at the first sign of a pest or disease problem?** Staff may disrupt a program by over-spraying rather than take the risk of losing their jobs or attracting negative attention because of pest prob-

lems. We've seen it happen! Training of both management and key staff in IPM, and a shared approach to decision making, will make everyone feel a stakeholder in the program.

- **Do you have a firm handle on the costs of IPM?** The full benefits of IPM can only be obtained over time. Long-term sustainability and improved business profitability is a goal IPM can help provide. You need to know what the projected costs of all the reasonable options might be, and at what point you need to stop one option and go for another. The cost of pest and disease management is generally a small part of the overall production cost for a crop.

Training in IPM is valuable for all staff

- **Do you have an IPM plan?** You should have one. An IPM plan can be a one-year, three-year or five-year plan, but without one you will have great difficulty moving forward and no yardstick to measure progress and make changes. Flexibility is an asset. Document procedures for staff in easy-to-understand language. Remember also that IPM is a package deal; it has many elements, and those elements need to work together. For example, you have decided you want to try controlling whitefly in poinsettias with parasitoids. If you haven't made provision for screening or closing off the greenhouse from that whitefly-laden *Gerbera* crop next door, or you have no idea how many whiteflies are already in your crop, or you haven't made provision for controlling fungus gnats or root rots, you don't have a viable plan. The money you spend on parasitoids would probably be wasted.
- **Are you afraid that adoption of IPM means accepting poorer quality in the finished product?** It doesn't. IPM only seeks to expand the list of management options available, not to force you to sacrifice plant quality for environmental quality. To have both is the overall goal, but commercial considerations will always dictate the acceptability of the finished product. IPM has the same or higher standards over the long term.



All staff should be trained in identifying pests

- **Have you talked about IPM with your customers?** You don't want to lose customers through a misunderstanding about your product quality objectives. Some customers may also want to market the environmental benefits of buying your product.

Staff considerations

Properly trained staff can be a great asset to an IPM program (and a liability if they are not), but they are indispensable to ensuring a successful outcome. A good dose of staff enthusiasm works wonders. Enthusiasm breeds on success, but knowledge is the cornerstone to success.

- **Is there an IPM training program for staff and management,** which is revisited regularly?
- **Are staff committed** to making IPM work?
- **Is reference material,** for example books and pictures, easily accessible to staff to help them identify pests and diseases?

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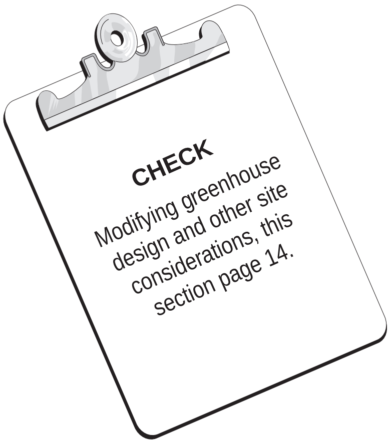
- **Do you have a checklist of tasks for staff and management** so that both know their responsibilities and follow-up actions needed?
- **Are staff delegated responsibility** for some aspects of IPM, so that they feel like stakeholders?
- **Do staff have access to coveralls or clothing** that doesn't attract pests (not yellow, mid-blue or white)?
- **Are washing facilities provided** to clean hands and tools?
- **Are special footwear or footbaths** provided in areas where soil pathogens are likely to be spread on shoes?
- **Do staff have a planned route** that takes them from clean areas to infested ones on the property?
- **Are staff dedicated to either propagation or production areas?** To minimise spread of pests and diseases, restrict movement of staff and equipment between propagation and production areas, and clean and infected areas.

Windbreaks are an effective, preventative measure for minimising spread of pests



Site considerations

A messy, weedy, poorly drained, poorly managed and badly structured site is a recipe for problems in crop production, and a poor backdrop to implementing a successful IPM program. The problems within the site need to be tackled first, before you implement an IPM program.

Prepare a property plan, noting the area and location of all growing areas (greenhouses, shadehouses, field plots, etc.), roads, rubbish disposal tip, soil, pot and media storage, propagation areas and areas for public access. Examine these from a quality management viewpoint and incorporate pest management needs. What changes can you reasonably make that will lessen the chance of pests and diseases invading your crops? Here are a few points.

- **What is the prevailing wind direction?** Does it come from a pest-rich area? Would a shelterbelt of appropriate trees reduce wind velocity and act as a screen? Is an artificial windbreak a possibility? For greenhouses, is the high-risk side of the house appropriately screened?
- **Does the layout predispose the site** to constant re-invasion by pests blown in or flying in from neighbouring crops or field-grown material? Can the layout be changed?

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1997#003, 008, 010
1996#004, 005, 013
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Hygiene (clean paths) between greenhouses is important

Badly maintained dump sites breed pests and diseases

Weeds in crops are not recommended. Always use sticky traps correctly, or not at all (note discarded sticky trap)

- **Do the public have access to propagation areas** where they can introduce or spread pathogens and pests?
- **Are discarded, infested plants composted in open areas** where pests can be blown in or fly back to crop areas? Are discarded plants left in the field, unsold and unloved, until they die or the next crop goes in? Crop debris should be removed from the site, or buried or composted under black plastic away from production areas.
- **Do you have a screened quarantine house** for receiving new plant material and another for unsold stock returning from the market? Do you keep favourite plants long past their sale-by date?

Refuse bins for collecting plant debris are a good idea

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Weed management
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- **Have you organised your production areas** to minimise the spread of pests and diseases? For example, you might consider keeping plants susceptible to spider mite together and away from hot, dry areas.
- **Would you like to beautify the site?** Permanent landscaping plants, other than grass lawns, have a high risk of carrying pests and virus through the seasons. Choose them carefully.
- **Weeds,** particularly flowering species such as clover, harbour spider mite, thrips, whitefly and virus. What is your management program for weeds?
- **Is the site drainage good,** or are there areas where pathogens and fly pests can proliferate in standing or temporary water? Is the dam properly maintained and is only treated water used for crops?
- **Does drainage water** move from pot to pot?

Physical considerations

This section is intended primarily for ornamentals grown in protected structures, particularly greenhouses. Plants grown in open situations can also greatly benefit from a consideration of the physical environment. For example, properly constructed artificial or natural windbreaks reduce wind speed and modify the environment of sheltered areas, improving plant quality and uniformity.

CHECK
Effective irrigation management, this section page 18.

In a greenhouse, the aim is to grow plants in an environment that encourages strong, healthy growth. Unfortunately, greenhouse environments are also potentially well suited to the initiation and development of pest and disease problems. They can also encourage or discourage the presence of natural enemies.

Fungus gnats and shore flies breed up in poorly drained situations

Several preventative steps can be taken to minimise pests and diseases by manipulating the greenhouse environment and greenhouse design. It is an aspect of pest and disease management that is often ignored, yet can have a great impact on the success of IPM in this environment.

Greenhouses can be a haven for pests and diseases. Conditions that favour pest and disease outbreaks include:

- **high temperatures,** leading to rapid development of pest populations and disease infections
- **high humidity,** leading to disease outbreaks through greater survival and germination rates of spores and surface growth of pathogens, particularly when temperature is also high
- **free water,** for example condensation or pools of water and fertiliser at ground level, favour infection by pathogens and insect pests such as shore flies
- **low humidity,** which along with high temperature favours spider mite development

- **open structures** with unscreened vents and doorways, which let flying and wind-blown insects into the greenhouse
- **stressed plants,** brought about by high temperatures, poor nutrient management, and dry or waterlogged conditions.

Quarantine incoming stock in a screened area. Monitor stock carefully before moving it to your main production area

Where natural enemies are introduced or exploited, the environmental conditions in the greenhouse may need to be managed to accommodate both the needs of the crop and the beneficials. Unfavourable conditions include high temperatures (above 30°C), low temperatures (below 15°C) and low humidity (below 60%).

Manipulating the greenhouse environment

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Temperature and humidity are the two environmental factors that have most influence on pest and disease establishment and development (Table 1). Their control is the major challenge facing growers in Australia, and a key element in any IPM strategy in the greenhouse. Some crops have highly specific temperature and humidity requirements to optimise productivity. Crop specific information may be necessary to develop an effective program that optimises both plant growth and the needs of beneficials.

Table 1. *Generalised optimum daytime conditions for greenhouse crops*

Air temperature	20° to 25°C
Relative humidity	60% to 80%
Carbon dioxide	340 ppm to 1000 ppm
Air movement	0.5 to 1.0 m per second

Modifying temperature

In addition to identifying the optimum temperature range for each crop, it is also important to know the range of values that impede growth and the levels that create stress and cause injury.

The temperature that exists within a greenhouse environment is the result of many interacting processes. These include solar radiation intensity, optical transmission properties of the cover, thermal properties of the crop and greenhouse floor, transpiration rate of the crop, greenhouse ventilation rate and numerous other energy transfers and exchange processes.

A basic understanding of what determines the air temperature of a greenhouse can be gained by considering daytime high temperatures and night time low temperature conditions separately.

Managing high temperatures

During the day, the greenhouse air temperature for a particular locality and greenhouse structure is dependent on the solar transmission properties of the covering. For most greenhouses, the covering material will have a solar transmission rate greater than 85%, with about 75% net passing through the covering and structural frame into the greenhouse and about 10% being absorbed by greenhouse structural materials. Timber-framed structures will allow less solar radiation through due to the greater shadowing by wider structural members.

The actual air temperature reached during the day within the greenhouse, for any given intensity of solar radiation, is dependent on the proportion of heat energy that is transferred directly back to the greenhouse atmosphere through convection. This amount can vary greatly. At times, it will be only 30% of the solar energy inside the greenhouse, and at other times it will be 70 to 80%.

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Greenhouse cooling
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The reason for the difference is the ability and opportunity for the crop to transpire (or evaporate water) and the amount of foliage intercepting the solar radiation. A greenhouse with areas of exposed dry concrete floor will be a lot hotter than a greenhouse with full foliage cover of a well-watered crop. In the latter greenhouse much of the solar energy is used in the energy expensive process of transpiration. It is therefore important to ensure all plants have an ample supply of readily available water and the greenhouse growing space is managed to keep bare floor area to a minimum.

Managing low temperatures

Without solar radiation, the greenhouse air temperature is primarily dependent on the heat transfer rate (by conduction) through the covering and outside climatic conditions. Both the outside air temperature and cloud cover are important. The significance of the cloud cover is that heat energy can be lost by thermal radiation, and this is dependent on the temperature of the sky (it is low if there is no cloud cover) and the long wave radiation transmission properties of the covering. Some materials, such as glass, are good at stopping long wave radiation, whereas other covering materials, such as basic polyethylene, are poor at stopping long wave radiation.

The lowest expected temperatures at the site, the temperature requirements of the crop, the thermal performance of the greenhouse and the characteristics of the heating system all need to be taken into account. Expert advice should be sought. Inefficient and ineffective heating systems can be a source of serious deficiencies in greenhouse production facilities.

Examples of deficiencies that may arise in heating systems include:

- inadequate heater capacity (unable to maintain temperature under some climatic conditions)
- poor heat distribution, leading to hot and cold spots
- excessive drying of crop due to high-speed delivery of hot, dry air
- ineffective control due to incorrect positioning and/or installation of temperature sensor.

These deficiencies are independent of control of heat loss through thermal screens, double-skin plastic, sealed doors, etc.

Using heat to control carry-over of pests

Carry-over of pests can be avoided by closing empty greenhouses and solarising (heating the soil/media to high temperatures by using solar energy) the soil and internal structure where residual pests might be found. Success depends on removing all crop residues and weeds and maintaining very high temperatures for at least a week, and preferably longer.

Modifying relative humidity

To achieve healthy growth, air moisture conditions need to be maintained to allow water molecules to move from within the leaf to the surrounding air. The amount of moisture in the air is described by the term relative humidity. Relative humidity is a measure of the amount of moisture or water vapour in the air at a particular temperature, compared to the amount required to saturate the air. Air has only a limited ability to hold water vapour before it becomes saturated. A cubic metre of air at 20°C can only hold about 15 g of water vapour. If the air actually has 7.5 g at 20°C, then the relative humidity would be 50% (7.5/15 x 100 = 50%).

For most plants, the general rule is to maintain a relative humidity in the range of 60 to 80%. Lower levels can cause stress and higher levels may restrict plant growth due to reduced transpiration. Higher levels may also encourage disease.

Changing the air temperature will change the relative humidity as the air's ability to hold water vapour increases with increasing temperature and decreases with decreasing temperature. Under typical greenhouse conditions, when the air temperature is mild (15° to 20°C) and relative humidity is high (over 50%), a change of 1°C will result in a change in relative humidity of about 4 to 5%. Relative humidity may change very rapidly.

Condensation

The presence of condensation or free water in the greenhouse should alert you to several potential problems.

The formation of droplets on foliage is generally a greater potential problem than condensation drops on the inner surface of a greenhouse covering. Leaf wetness, particularly in conjunction with low temperatures, is the source of several disease problems, including *Botrytis*, bacterial leaf disease and rust. Careful attention should be paid to growing areas close to the edges of greenhouses, as it is often in these areas that relative humidity will be high and problems will develop.

Fogging systems, as opposed to misting systems, produce fewer problems with condensation because the water droplet is much smaller and tends to evaporate before settling out.

Preventing condensation

Drops on the inside surface of the greenhouse cover are a worry. They reduce the amount of light that is transmitted into the greenhouse and absorb some of the heat. Falling drops may wet leaves, which may encourage some fungi to develop. These drops can bruise sensitive foliage and flowers, cause soil splash from pots and punnets, and devastate plug trays. Falling drops are also a nuisance to staff working inside the greenhouse.

Condensation can be prevented in the following ways:

- **Install air circulation fans** in greenhouses where natural air movement is poor. Fans encourage a more even environment and prevent the localised build-up of water vapour.
- **Use plastic films that incorporate anti-droplet formation chemicals**. These film treatments have a limited life because of the way in which the chemical is released from the film. It is difficult to accurately predict the longevity of their effectiveness because that depends on the rate of formation of condensation on the covering surface and general greenhouse climatic conditions.
- **Vent in the evening to dump excess moisture** and keep leaves and stems dry at night, when greenhouse air temperatures are often low. A general recommendation is that extended periods (three to four hours) of high humidity should be avoided. In some circumstances the heating system can be used in conjunction with the ventilation system to achieve a drying and purging of the moist greenhouse air.

Ultraviolet and infra-red filtering films for modifying pest and disease development

There are opportunities to reduce the potential problems with pests and diseases by using plastic greenhouse coverings with special optical properties. Such plastic films filter out certain wavelengths to produce the desired effect.

Ultraviolet (UV) filtering plastics

Ultraviolet (UV) filtering plastics can inhibit development of fungal diseases and prevent insect pest establishment by adversely affecting their behaviour.

In the mid 1980s Canadian research demonstrated that filtering out UV up to 380 nanometres (nm) reduced *Alternaria solani* in tomatoes by 50%. Israeli, Japanese and UK studies reported reductions of *Botrytis* on tomatoes by 58% and cucumbers by 48%, and in primula and strawberries, and also against *Sclerotinia* and *Stemphylium*. Israeli research has also demonstrated that removing UV will suppress the activity of some species of thrips, whiteflies, leafminers and aphids by interfering with their vision, which operates in this range.

The influence of UV filtering plastics on beneficial species is unknown. The insect-proof screening product BioNet®, constructed from polypropylene containing UV-A and UV-B absorbers, is designed to provide an optical and physical repellent effect on flying insect pests.

The removal of the UV component of solar radiation (less than 400 nm) is not considered to have any detrimental effect on the photosynthetic potential of crops. Plastics vary greatly in their ability to transmit solar radiation. Greenhouse polythene films tend to transmit strongly, greater than 85%, in the photosynthetically active range of 400 nm to 700 nm. In many Australian situations, the greenhouse cover transmits much more photosynthetic light than the crop needs.

Infra-red filtering plastics

Infra-red filtering plastics reduce the heat in the greenhouse by blocking out about half of near infra-red rays without interfering with photosynthesis. About half the energy from the sun is in the infra-red range of 700 to 2500 nm.

Incorporation of colour pigments in the plastic can improve the spectral balance, for example by improving blue to red light ratio. In addition, incorporation of fluorescence can increase emission of red light. These products need to be evaluated under Australian conditions of high light to assess their effectiveness.

Physical exclusion of pests

John Bunker, from Redlands Nursery in Queensland, says:

"We screened our quarantine house, which is used for either holding plant material for interstate distribution of young plants, or transfer of our plants to our other property, and reduced the incidence of pests and diseases."

Physical exclusion of pests can involve the incorporation of sealed doorway entry rooms, insect-proof screening, air filtration and the establishment of air pressure zones that maintain atmospheric separation between areas. In an IPM system, exclusion of pests should be one of the first tactics considered to reduce the need for other control measures.

Insect-proof screens can prevent entry of flying and wind-borne insects. Screening with UV-filtering plastic may have the added benefit of an adverse effect on the behaviour of pests. The use of insect-proof screens is now more cost effective than in the past due to the rising cost of pesticides and increased worker protection regulations, however, fitting screens to an existing structure can be expensive.

The effect of screening on the air-handling characteristics of the greenhouse can be significant. Hole size and shape, and material construction all have an influence on the amount of resistance created by the screen. Selection of a screen with an optimal hole size is very important (Table 2).

Table 2. *Guide to pest size and suggested screen hole size*

Pest	Thorax width (mm)	Abdomen width (mm)	Suggested hole size (mm)
Western flower thrips	0.215	0.265	0.192
Silverleaf whitefly	0.239	0.565	0.462
Greenhouse whitefly	0.288	0.708	
Green peach aphid	0.434	2.295	

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Screening materials and properties

Screens are available as knitted, woven-type fabrics and as perforated sheets or films. Both steel and plastic (polythene and polyester) yarns are available. Aluminised screening-fabric has been shown to repel thrips, aphids and whiteflies. It has also demonstrated repellent effects when placed as strips around doorways and vents, and as an area-treatment on sidewalls in place of other screening materials.

Sidewall screening is an effective way of excluding pests from the greenhouse

Insect pests can enter through roof vents; these should be screened as well

Factors to consider before installing screens

- **Where do most of your pests come from?** If most pests enter from outside to seasonally infest the crop, screening can have real benefits. Remember that screening will keep pests in as well as out. Good management and access restrictions to the greenhouse are needed to minimise insects getting inside on staff and plants.
- **Which pests are you trying to exclude?** Flying insects such as thrips, whiteflies, aphids, leafminers, fungus gnats, shore flies and moths should be excluded. The smaller the pest, the more expensive the screen and the installation cost.
- **Is total exclusion necessary?** The amount of exclusion will depend on the type of crop being grown and its value. A propagator can benefit from selling virus or disease-free stock. Pest-free stock is essential for any IPM program, particularly where biocontrol is being used.

  If total exclusion is necessary, consider all the areas where the target pests could enter, for example doorways, vents, greenhouse seals and material, and staff entering the greenhouse. If a reduction of the pest population is adequate, a larger hole size in the screening material may be suitable. A smaller hole size on the upwind side may be a compromise, as is screening vents and doors only on the most exposed side of the greenhouse.
- **Types of pest to be excluded and the level of risk.** Does the crop suffer from pests during the entire growing season or is it seasonal? Are different pests involved? For effective exclusion, compare insect size to hole size of the screen. The average abdomen width of western flower thrips females is 0.265 mm and a hole diameter of 0.192 mm is recommended for exclusion (Table 2). In practice, field trials have shown that in many cases screens designed for whiteflies can effectively exclude thrips (Table 3). Researchers are still gaining experience on the most appropriate hole sizing for pests in Australian conditions.

  When deciding between effective exclusion and airflow, a reasonable compromise is to use the whitefly size screen, particularly where the greenhouse is naturally ventilated.

Table 3. *Insect screening materials available in Australia*

Screening product	Material	Hole size (mm)	Pests excluded
Meteor Anti-virus Net	Polypropylene	0.29 x 0.80	Whiteflies, aphids, fungus gnats, moths
BioNet®#	Polypropylene–UV stabilised	0.29 x 0.80	Whiteflies, aphids, fungus gnats, moths
LS SF Aphid	Polyester	0.28 x 0.78	Whiteflies, aphids, fungus gnats, moths
LS Thrips 'T'	Polyester	0.15 x 0.35	Thrips and others

Comprising polypropylene with UV absorbency in the UV-A and UV-B range for added effect.

Effect of screening on ventilation

Forced-air ventilation systems using fans can readily accommodate the airflow resistance caused by the installation of screens, *so long as appropriate engineering procedures are followed*. The performance characteristics of the fans and the airflow performance of the greenhouse need to be taken into account. The resistance to airflow across the screen is commonly expressed as a pressure (Pascals or Pa). Typically, systems are designed with a pressure drop of 20 to 30 Pa across the screen. High-pressure drops are experienced with high airflow rates and small screen hole sizes. Blocked screens also cause a high-pressure drop. Formulae are available to calculate the air dynamics.

The impact of the installation of a screen barrier in a naturally ventilated greenhouse structure can be dramatic. The convective forces, those created by the natural movement of hot air, driving air movement under naturally ventilated conditions are small compared with the potential resistance of the screen. A high greenhouse with large ventilation openings will provide the best chance for successful screening. Plastic or fibreglass sidewalls may need to be replaced with screening. In either case, the vent area will need re-engineering to ensure an adequate airflow.

The approach to selecting screens for your greenhouse should take account of airflow resistance of the screen and the total area of screen required to achieve the desired airflow rate. In practice this may mean accommodating a screen area three to four times the original unscreened inlet ventilation area (see picture Section 2, page 11).

Advantages and disadvantages of insect-proof screening

There are several advantages and disadvantages of insect-proof screening in greenhouses (Table 4).

Table 4. *Advantages and disadvantages of Insect-proof screening*

Advantages	Disadvantages
Reduced introduction of insect pests	Difficulties in selecting hole size and fastening
Reduced need to spray	Reduced ventilation
Reduced exposure to pesticides	Regulated access to greenhouse*
Improved plant health	Screen maintenance
Happier staff	Pests can be screened in as well as out

* Regulated access to greenhouses has advantages (improved security) and disadvantages (restriction of easy movement of stock and staff).

Modifying greenhouse design

It is almost impossible to produce a consistently good crop in a badly designed greenhouse. Both crop production and IPM principles are much easier to apply where you have control of inputs and outputs. Modifying greenhouse design is very difficult to do retrospectively, at least at a practical cost, but a bit of forward planning in the expansion or start-up phase can save a great deal of frustration down the road.

The two major components of greenhouse design relevant to IPM are **site planning** and **structural issues**.

Site planning

Important aspects of site planning include:

- position of the greenhouse in relation to other enterprises on the property
- orientation of the greenhouse to appropriately use light levels
- provision for expansion of production area
- access to services and roads
- structural requirements of building, including building regulations
- selection of the most appropriate greenhouse design for the crop, site and enterprise
- internal layout plan of the greenhouse and crop production system
- selection of environmental modification technologies.

Site planning should include the provision of a buffer zone (vegetation-free area at least 2 m wide, but preferably 10 m) around the greenhouse to limit the opportunity for pests to live on adjoining plants. Roads should be constructed so that they remain sound and drain readily under all weather and vehicle conditions. Poor roads can lead to problems associated with the transfer of mud or soil around the property. Greenhouses should also drain properly; laser levelling may be necessary for a new structure. Bulk storage areas should be protected from the weather and well drained to reduce the risk of contamination of materials by drainage water and dust.

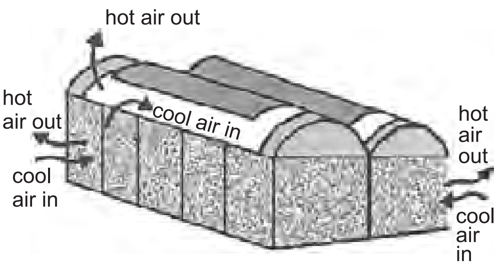
Structural issues

In the greenhouse, consideration should be given to roof shape, eaves and roof height, and provisions for cooling and venting.

Greenhouse roof shape

Greenhouse roof shapes range from flat (horizontal), gable (pitched), through to curved (or tunnel). The shape influences two critical aspects of the greenhouse environment: the **level of light transmitted** and the opportunity for **natural ventilation** (see figure next page).

Continuously curved roofs transmit the greatest amount of sunlight throughout the year. The best shape for natural ventilation is the gable roof. The positioning of the vent at the ridge and the straight converging sides encourage a faster and more uniform exit of air through the vent opening. Curved roofs, which have a flat section in the top of the roof, do not exhibit this characteristic. Pockets of hot air can be trapped within a curved roof.



Gutter connected system

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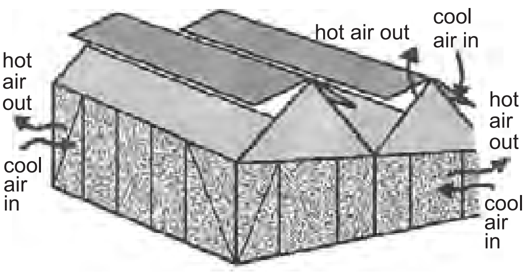
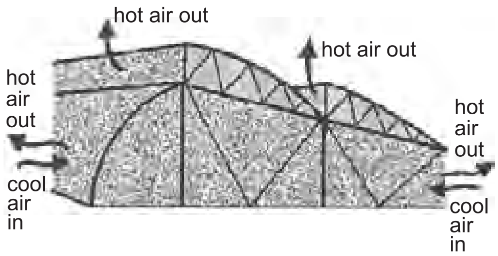


Double gull-wing system



Saw tooth system

Different roof shapes and ventilation systems for greenhouses

The angle of internal surfaces is important in terms of formation and handling of condensation in the greenhouse. Roof shape, therefore, has an impact on condensation management. Condensation will move down a material surface if the slope is greater than 23 degrees. It can then be collected and drained. When condensation forms on flat or shallow surfaces, it tends to remain and relatively large drops are formed. These can fall under their own weight or be dislodged by movement of the structure or covering. For example, a tunnel greenhouse with a section of flat roof is prone problems with formation of condensation droplets and falling drops.

Other consequences that relate to roof shape are being able to fully use all the growing space (sloping sides can restrict the use of space) and higher heating costs for a larger surface area (high tunnels compared to low flat roof). As a general rule, roofs with a slope angle of less than 17 degrees should not be used. The low angle tends to allow rubbish (for example, leaves) to accumulate on the roof and not be washed off by rainfall.

Greenhouse height

The height of the greenhouse has some important implications for the quality of the greenhouse environment. Increased height provides increased air volume with which the crop can interact. Tall greenhouses generally have more stable environments, lower maximum temperatures and less variability in climate. The larger air mass surrounding the plant is a source of carbon dioxide during the day. It also allows water vapour to move from the surface of foliage to the atmosphere and it acts as a sink for excess heat from the plant foliage.

Modern greenhouses are built to a gutter height of not less than 3 m (Table 5). An overall ridge height (highest part of the roof) of not less than 4 to 5 m is desirable. This height is required to accommodate environmental control equipment such as internal screens, lighting and fogging systems.

***Table 5.** Advantages and disadvantages of increased height in greenhouse roofs*

Advantages of increased height	Disadvantages of increased height
More stable environmental conditions due to greater air mass	Increased cost of construction
Lower maximum air temperatures	Increased side loads on structure due to wind
Less fluctuations in relative humidity (healthier crop environment)	Heavier structural components and possibly increased shading of crop
Crop foliage further away from hottest air at top of greenhouse	
Ability to regulate greenhouse environment	

Greenhouse ventilation

Effective ventilation is the single most important performance feature of Australian greenhouse structures. Growers can use **passive** (natural) or **forced** (fans) ventilation systems.

Effective ventilation is essential for:

- preventing excessive greenhouse air temperatures
- controlling relative humidity
- admitting fresh air
- adequate crop transpiration rates
- providing stable greenhouse environments (minimum fluctuations in temperature and relative humidity) and uniform conditions throughout the crop.

Natural (or passive) ventilation

The design of naturally roof-ventilated greenhouses requires attention to some critical dimensions. They are:

- total roof-opening area, for example minimum 20% of floor area
- ample height of top ventilator, for example greater than 2.5 to 3.0 m above ground
- generous inlet area
- ample height difference between inlet and exit opening, for example greater than 2 m.

The control of relative humidity is strongly dependent on the ability to achieve low ventilation rates and uniform air movement throughout the greenhouse crop space. Vent opening actuators, which have infinitely variable adjustment from zero to 100% opening, are valuable in maintaining the relative humidity within optimum levels.

The degree of control of passive ventilation systems is dependent to some extent on the type of ventilator. Ventilator designs include window or hinged-framed, roll-up fabric or inflatable ducting. Each of these designs can be mechanised and automated. Window or hinged-frame type ventilators, operated with linear actuators, provide the highest degree of incremental control.

Fans (forced-air circulation) and ventilation

In Australia, there has been strong interest in the use of internal air circulation fans in greenhouses. The continuous air movement they generate provides a more uniform environment and assists in the drying of foliage.

The removal of all air from within the greenhouse is sometimes best achieved using fans. The most common arrangement is to position fans at the end or sides of the greenhouse to extract (exhaust) the air from the greenhouse. The fans need to be selected to remove the air at the correct rate and also be capable of overcoming any resistance to airflow caused by ventilators, screens and the crop. High ventilation rates, for example, 40 to 60 greenhouse volumes per hour, are required to control temperature. Much lower rates are required to control relative humidity, for example 5 to 10 air volumes per hour.

If the greenhouse is equipped with temperature control (high capacity) fans, operating these fans for short periods can control relative humidity. Some growers operate high capacity fans for short periods (a couple of minutes) every 15 minutes to dump excess moisture from the greenhouse. Relative humidity sensors can also be installed.

Greenhouse cooling

Cooling systems may be required if the greenhouse design and ventilation equipment cannot maintain desired conditions. Before cooling equipment is installed, be sure that you have adequate greenhouse height, effective ventilation and external or internal shading.

- **Shading** of the crop is an effective method as it directly reduces the greenhouse heat load and also reduces the intensity of the solar radiation incident on the crop foliage. Moveable shading screens allow shading to be in place only at times of high solar intensity. Knowledge of the light requirements of the crop is essential if shading is to be used. Shading in combination with positive air movement is often a satisfactory approach for many greenhouse situations.
- **Evaporation of water** can also be used to achieve significant cooling. Both evaporative cooling and fogging systems are commonly used. The effectiveness of the evaporative cooling process is directly dependent on the moisture content (relative humidity) of the air. If the air is dry, significant evaporative cooling can be achieved. If the air is moist, for example relative humidity above 60%, then the amount of cooling is limited. Table 6 shows that the amount of cooling obtained with air at 30°C and 40% relative humidity is 8.0°C but only 2.4°C at 80% relative humidity. Analysis of the local climate is important when considering evaporative cooling systems.

Table 6. *Temperature reduction with evaporative cooling*

Air temperature °C	Relative humidity %	Achievable evaporative cooling °C
25	40	6.8
	60	4.4
	80	2.0
	100	0.0
30	40	8.0
	60	5.2
	80	2.4
	100	0.0
35	40	8.8
	60	5.6
	80	2.4
	100	0.0

Note: This table has been developed on the assumption that 80% of the maximum theoretical temperature decrease would be achieved in field conditions.

The evaporative cooling process requires all cooled moist air to be continually exhausted or vented. Greenhouses, particularly fog cooled greenhouses, should not be closed during evaporative cooling. In addition, if misting (drops larger than fog) is being used to assist cooling, careful attention needs to be paid to the crop condition as the extended periods of high temperature and foliage wetness can initiate disease problems.

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Cultural considerations

There are several cultural procedures that will help prevent and manage pests and diseases in the crop. See *Handy Guide 2, Crop management for ornamentals*.

Effective nutrient management

Correct nutrient application will ensure high quality crops with the right amount of plant shoot and root growth and increased resistance to pests and diseases. Under-fertilised plants will be stressed and prone to insect pest and disease attack. Over-fertilisation can result in lush plant growth that is more susceptible to aphids and other sap-sucking insects. For example, excess nitrogen and potassium will result in plant toxicity, burning and scalding damage, and will predispose plants to disease infection and pest attack.

Cover your media storage area to help keep out seeds and dust

Appropriate levels of nutrients depend on the plant species, temperature, carbon dioxide and water (leaching, humidity). At temperatures below 15°C, plants have a lower nitrogen intake, and the composition of nutrients available to the plant should be low in nitrogen to avoid toxicity. High soluble salt levels such as calcium, magnesium, sodium and incorrect pH can encourage *Chalara* and *Pythium* root rot.

Effective irrigation management

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Correct irrigation procedures for each crop will prevent waterlogging or plants drying out. Plant species should be matched to the appropriate form of irrigation. Trickle, capillary and bottom-up irrigation systems, which apply water at the soil surface or at the base of pots, will extend the effect of foliar-applied insecticides, as the residues will not be washed off. Overhead sprinkler irrigation predisposes plants to foliar infection by pathogenic fungi and bacteria if plants do not dry by nightfall. Hygienic measures should be adopted to prevent or remove sources and spread of pests and diseases.

Sanitation management

Correct management of growing media and mixes, access to production areas, greenhouse structures, weeds and the crop is crucial to a hygienic environment.

Hygienic media storage for a small nursery

Media management

- **Ensure growing media is stored hygienically,** for example, in a front-draining concrete bin and away from traffic and weeds.
- **Avoid storing potting mix for too long** to prevent invasion by soil-borne organisms.
- **Pasteurise re-used media and sterilise recycled pots** to kill harmful soil-borne organisms.
- **Use quality raw ingredients**.
- **Dip dibble sticks in bleach** between batches to prevent transfer of pathogens.

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1997#003
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- **Maintain physical and chemical attributes** of particle size and shape, pH and electrical conductivity, all of which determine water-holding capacity, drainage and balance of nutrients in mixes and growing media.

People management

- **Prevent transmission of pests and diseases by people, machinery and tools** by frequent posting of clear guidelines on protocol and revisiting procedures**.** Clean hands (and tools) between batches when propagating, transplanting, dibbling or pinching.
- **Provide protective coats** for visitors and plastic overshoes. Restrict their access on the property.
- **Provide a footbath at entry to propagation and production areas** to disinfect shoes, or provide plastic overshoes.

Structure management

- **Keep greenhouse benches, floors, pathways, equipment and tools clean** and treat with bleach to kill infectious pathogens.
- **Clean greenhouses thoroughly between crops** and try to have a plant-free period, preferably in summer when the structure can be solarised.
- **Between crops, wash down structure** and plastic flooring with high phosphate detergent.

Wet and weedy situations this close to a greenhouse are asking for trouble

Concrete pathways can be cleaned and disinfected

Weed management

- **Remove all weeds** throughout the entire site, greenhouse and shadehouse. Broad-leaved weeds provide a refuge for insect pests such as whiteflies, aphids, thrips and spider mites, and diseases such as tomato spotted wilt virus, verticillium wilt and root rot nematodes.
- **Remove ornamental plants bordering greenhouses**; they are weeds. They may look pretty, but they harbour pests and diseases. Replace them with grass or a non-vegetative surface.
- **Maintain a 3 to 9 m weed-free barrier** around the greenhouse (and 2 to 10 m barrier elsewhere) by keeping weeds down or providing concrete or asphalt pathways. It is important to eliminate weeds around vents.
- **Install screens on vents** to limit the movement of wind-blown seeds into the greenhouse.
- **Use only clean plant material** and growing media to prevent the accidental introduction of weed seeds into cropping areas.

Hose ends should be kept off the ground

- **Consider covering** the floor area with plastic, fibre mats, gravel and/or concrete to prevent establishment of weeds.

Crop management

- **Choose crops and cultivars resistant to pests and diseases** where possible and schedule crop planting. Susceptible plants serve as an initial focus for insect pests and pathogen outbreaks. If less tolerant cultivars are grown, keep them together in one area so they can be monitored more often and treated; for example group spider mite-susceptible plants together, away from hot, dry areas, ends of benches and walkways where they are easily transferred on clothing.
- **Avoid propagating from seedling trays containing diseased plants**. Even the healthy looking plugs probably carry the disease pathogen.
- **Plant or place new crops in clean areas** where possible, *not* alongside mature or flowering crops.
- **Monitor mother stock** for pests and diseases.
- **Schedule crops** to minimise movement of plants and transfer of insect pests and pathogens from neighbouring land.
- **Quarantine incoming stock** and monitor carefully before adding it to your main stock.
- **Isolate infected plants for immediate treatment or disposal**. Virus-infected plants will not recover—throw them out!
- **Space plants** to avoid crowding and maximise air flow.
- **Manage dust.** Avoid situations where dust can spread plant diseases around the property.

Chemical considerations

Chemical use will remain an important tool in an IPM program. Effective results will be determined by which ones you choose and the way they are used.

When you are considering using chemicals in an IPM program, ask yourself:

- Is the treatment really necessary?
- If so, what is the least toxic of the effective options, for the shortest time?
- Will spot treatments be adequate?
- Does it fit within a resistance management strategy?
- Does it cause visible damage to plants?

You should aim to manage the problem, not necessarily to eradicate it. This advice applies to both pests and diseases.

Wayne Bacchi, of Wholesale Indoor Foliage in Queensland, has been practising IPM for 10 years. He says:

"The benefits of IPM include less reliance on chemicals and overcoming chemical resistance. Beneficial insects have better crop penetration than chemicals."

What you should consider before using chemicals

Growers who spray ornamental crops frequently are often amazed at the improvement in plant quality once they reduce the amount of chemical used as part of a targeted IPM program. Before you can do this, the following important steps will help your IPM program.

more info
Know your pests
Section 5

- **Identify the pest or disease correctly.** Mis-identification can result in an inappropriate chemical being used that will have no effect on the target organism. Know the organism's life cycle, and the stage most susceptible to the chemical.
- **Detect the problem early.** Always base any decision to spray on monitoring. Early detection may mean only a spot treatment is necessary, which reduces pesticide use and crop damage. For diseases, familiarity with environmental conditions that trigger an outbreak can be used to signal a need to apply preventative treatments.

CHECK
Handy Guide 4, Chemicals currently registered for common pests of ornamentals and Handy Guide 5, Chemicals currently registered for common diseases of ornamentals.

- **Select an appropriate, registered chemical.** Identify the most effective chemical, the one that is safer for you and your staff, and that will cause the least disruption to biocontrol agents if you are using them. Even if you are not releasing biocontrol agents into your crop, proper chemical selection, application and limited use may result in establishment of naturally occurring beneficials.
- **Understand the action of the chemical.** Is it systemic (translocated through the plant), translaminar (contacts one side of the leaf and moves across to the other side) or contact acting (must hit the target organism)? For systemic pesticides, soil applications may be safer for foliar-inhabiting biocontrol agents than top sprays. Is it preventative (many fungicides) or curative (most insecticides)? Is it short residual or long residual? Fast acting or slow?
- **Check the need for a wetting agent.** The label will indicate if one is needed. Don't add wetter where two chemicals are mixed in a tank. Most chemical formulations already incorporate a wetting agent. Too much will reduce the amount of active ingredient adhering to the foliage.
- **Rotate between pesticide chemical groups to delay resistance.** For difficult pests it may be necessary to apply a series of three properly timed applications of the same product. Monitoring will tell you whether to switch sooner to another type of pesticide and when another chemical group may be necessary. It is rarely possible to completely eliminate a pest, but it is almost always possible to keep it in check by combining effective products with other IPM practices.

  Remember that no pest has shown resistance to horticultural soaps and oils. These products may not be totally effective, but if soaps and oils thoroughly cover plants they can be a valuable tool to manage pests.

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2000#01
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more info
Handy Guide 6,
Chemical toxicity to
biocontrol agents

- **Be aware of harmful effects of chemicals on natural enemies.** Obtain toxicity and side effects data for chemicals registered for ornamental plants. This will help you identify biorational ('soft') chemicals suitable for use with natural enemies that enter from surrounding areas or are deliberately introduced.
- **Read the label.** It contains important information on pests or diseases controlled, appropriate crops, where the product can be used, phytotoxicity and safe use. If the product is not effective at label rates and conditions, and you are sure you have obtained good coverage, it is possible that the pest or disease is no longer susceptible to that product. It is never 'okay' to increase the rate. Both decreasing and increasing the rate may precipitate or further exacerbate resistance. In some circumstances it may be acceptable to decrease the rate if, by doing so, you preserve natural enemies that are present.

> ***Always read the label.*** *Users of agricultural chemical products must always read the label and any permit before using the product, and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.*
>
> *Labels can contain warnings about inappropriate usages that can help growers avoid phytotoxicity, improper tank mixes or hazardous working conditions for employees.*

more info
Sprayers and spraying
This section page 23

- **Select the appropriate application equipment.** Poor coverage, rather than pest resistance, is often the reason for chemical failure. Defective equipment will give poor coverage. Be aware of the different types of chemical application methods and what might be appropriate for your situation. Calibrate spray nozzles so that you know their output. Ultra-low volume (ULV) applicators need fans to distribute the droplets through the crop. Pests are generally on the lower leaf surface and that is where most high volume (HV) spray droplets need to be placed.
- **Time your sprays.** Ultra-low volume sprays cannot be applied to crops grown under protected conditions during the heat of the day because the greenhouse must be closed and the fans turned off. High volume sprays in the midday sun may burn the crop because of rays shining through large droplets. Some pesticides, such as pyrethroids, lose their efficacy at high temperatures. Pests such as thrips are often active in the late afternoon and early morning, and this is the best time to apply a treatment.
- **Avoid unnecessary spraying.** Try to limit spraying to spot sprays if that is all that is required. Scouting data will give you this information. Blanket spraying is costly, can damage the crop, and can prevent establishment of natural enemies.
- **Acquire an appropriate weighing balance** that will allow you to accurately measure small amounts of powder formulations. This will avoid the temptation to mix up large volumes and 'use it up somewhere' or increase the rate because you can't measure out such a small amount.
- **Know the water quality**. Water quality is important for chemical efficacy. Water with a pH 7 or higher (alkaline) or hardness from calcium, magnesium or other ions can result in reduced pesticide efficacy. Insecticidal soaps precipitate when mixed in water with high calcium and magnesium levels. All diluted pesticides should be used soon after mixing and not stored for longer than a few hours.
- **Correct chemical storage.** Poor storage conditions can reduce the shelf life of a chemical. Powder formulations, on average, will last longer than liquid formulations. Excessive heat will accelerate chemical deterioration. Store chemicals in a cool, dry place and keep herbicides in a separate storage container.
- **Protective equipment.** Always wear appropriate protective clothing and equipment. This should include, at least, a cover suit, boots, gloves and facemask with correct filter. Household gloves are not appropriate. Change masks regularly; you should not be able to smell the pesticide.

Always protect yourself when mixing chemicals and spraying

Launder clothes separately from a normal wash. There are many leaflets describing acceptable wear. In addition, check the pesticide label for information.

- **Separate sprayers.** Keep a separate sprayer for 'soft' pesticides to avoid accumulation of residues toxic to biocontrol agents. Never use the same sprayer for herbicides and pesticides.
- **Post signs.** These alert staff (and customers) to areas where you are about to apply pesticide and any re-entry precautions. If you do not want certain pesticides applied in an area, for example if you are using biocontrol agents, a sign here can save costly mistakes.

What are the problems with chemical control?

Most problems with chemical control are due to the wrong type of spray equipment being used or its incorrect usage, leading to poor coverage.

Other problems include:

- **Pests and diseases developing resistance to chemicals**. You may be developing your own hard to control strain or bringing already resistant pests into the property with new stock.
- **Several chemicals have been withdrawn, or are being considered for withdrawal from use**. The National Registration Authority for Agricultural and Veterinary Chemicals (NRA) is reviewing existing chemicals. For example, parathion ethyl and monocrotophos have been withdrawn and the use of endosulfan has been severely curtailed.
- **Changes in legislation,** making pesticide use by growers even more difficult and expensive. Growers who want to use endosulfan, for example, must, among other things, have completed the ChemCert certificate.
- **Spraying toxic chemicals**, or working in treated crops; no one enjoys this.
- **Re-entry conditions into sprayed areas,** which can impose restrictions on handling the crop.
- **Finding a convenient time to apply pesticide, particularly for a retail operation**. This may be a difficult decision, as crops may need spraying when customers are absent and staff may need to work overtime.

What you need to know about sprayers and spraying

Droplet size

Droplet size is important. Research has found that small droplets (30 to 120 microns in diameter) are most effective. The optimal size will probably depend on the size of the target and the type of action of the pesticide. Many small droplets are more effective than a few large ones. However, contact non-residual pesticides, such as oils and soaps, must be applied as HV sprays to run-off. As a general rule, the larger the droplet size, the larger the spray volume needed for adequate crop coverage.

Application methods

There are three main types of application method:

- **High volume (HV)** over 1000 L/ha (variable droplet size, many greater than 100 microns in diameter, possibly as large as 700 microns).

- **Low volume (LV)** 100 to 400 L/ha (droplets 30 to 100 microns in diameter).
- **Ultra-low volume (ULV)** under 100 L/ha (droplets smaller than 30 microns in diameter).

All applicators have a place in effective pest management.

High volume sprayers

High volume sprayers are the most commonly used method for applying pesticides in greenhouse and outdoor ornamental crops. Equipment and methods haven't changed much over the years. Equipment includes:

- hand-held pump sprayers
- knapsack sprayers
- larger sprayers often powered by electric or fuel driven motors.

High volume sprayers produce droplets of varying sizes by forcing air through a nozzle, usually of the hollow-cone type, that breaks the tank mix of chemical and water into droplets. These sprayers are used for applying insecticides, miticides and fungicides. Larger sprayers usually have a hand wand on the end of a long hose that has to be dragged up and down rows or aisles to apply the mix to plants.

At present there does not appear to be a commercial HV greenhouse sprayer made in Australia. Many growers adapt field sprayers. Table 7 shows the recommended criteria for a HV greenhouse sprayer.

***Table 7**. Essential criteria for a HV greenhouse sprayer*

Tank size	50 – 100 L
Power	240 volt or petrol
Sprayer type	Recirculating hydraulic with pressure regulator and gauge
Application method	Hose and hand wand with twin or triple head nozzles
Length of hose	Not less than 50 m, retractable
Pressures	300 – 500 pounds per square inch/40 – 70 kPa
Nozzles	Multiple hollow-cone producing fine to medium droplets, preferably closer to 100 microns diameter
Spray distance	Up to about 6 m
Size	Portable, on wheels, about 45 – 60 cm wide, easy to manoeuvre

Advantages of HV sprayers

- High volume sprayers are the only legal way to apply most pesticides in greenhouse and outdoor situations because pesticide labels are mostly written for HV application.
- Good coverage can be achieved by using high pressure, smaller nozzle holes to produce smaller droplets, good penetration and turbulence within the canopy.
- Equipment is widely available and relatively inexpensive.
- Desirable for applying oils and soap sprays where a wet coverage is required.
- Suitable for spot treatments.

- Well suited to controlling certain pests, for example infestations of scales and mealybugs.
- Can be modified to suit conditions, for example fan assist, vertical or horizontal booms.

Disadvantages of HV sprayers

- Time consuming.
- Often inefficient (usually only 2 to 6% of pesticide reaches the intended target).
- Wasteful of chemical.
- Many droplets are too small or too large to be effective.
- Environmentally undesirable because of run-off potential and drift.
- Create staff re-entry problems.
- Nozzles must be changed regularly to guarantee spray droplet characteristics.

Low and ultra-low volume sprayers

Several types of low (LV) and ultra-low volume (ULV) sprayers are available. The amount of pesticide used per unit area is generally much reduced because of increased efficacy. High-volume rates of active ingredient are not applicable to low-volume applicators.

Rotary mist applicator (or controlled droplet applicator, CDA)

Rotary mist applicators disperse chemical by directing the flow onto a spinning disc that causes the liquid to break up into small droplets 10 to 60 microns in diameter. A fan behind the discs creates a turbulent air-stream. The applicator is able to disperse 2.5 to 10 L/ha. Mixture deposition is good, but canopy penetration can be inconsistent, depending on crop density.

Thermal fogging machines

Thermal fogging machines are the most common LV applicators in greenhouses and the fastest method of chemical application. They can be as much as 50 times faster than HV sprayers.

Thermal fogging machines need a special carrier that improves the uniformity of droplet size and distribution. The carrier also decreases the droplet's molecular weight, allowing the particles to float in the air for up to six hours and travel more than 60 m.

Most foggers disperse liquid or wettable powder formulations. Pesticide is injected into an extremely hot, fast-moving air stream that vaporises it into fog particles, usually from 10 to 50 microns in diameter. Air circulation from horizontal airflow fans in the greenhouse will give more uniform coverage and better foliage penetration. High temperature and low humidity will result in droplets settling faster and increased deposition on the upper surface of plants. It is important, especially with wettable powder formulations, that the fog is aimed over the crop at a 30 degree angle to avoid immediate deposition on plants in front of the machine.

Pesticide coverage on the undersides of leaves may be inadequate to obtain effective control of pests such as two-spotted mite. Thermal fogging machines are not suitable for spot treatment.

Cold fogging machines (aerosol generators)

Cold fogging machines have largely replaced thermal fogging machines. They use high-pressure pumps to draw liquid from a tank through an atomising nozzle to produce fog-sized particles, which can vary in size depending on the machine being used.

Ultra-low volume machines can operate automatically, using a timer, and an operator need not be present, but proper machine placement and air movement are critical to ensure maximum coverage. The fog is most commonly distributed with the assistance of external horizontal airflow fans or fans built into the machine. The distance and area covered by the fogger depends on the capacity of the fan(s). The LV machine disperses a high-pressure (2800 to 3000 psi) fog from a hand-held spray gun at the end of a hose reel.

Both ULV and LV machines can apply a wide variety of chemical formulations in a highly concentrated spray solution.

Electrostatic machines

Electrostatic machines use compressed air to form droplets of about 30 microns in diameter, which travel through a nozzle where they become electrostatically charged. The charge helps to create uniformly sized particles that disperse because they repel each other.

Charged particles are attracted to leaves and some plastics. Coverage is uniform because a charged particle, when it strikes a surface, creates a momentary overcharge that repels other particles. Electrostatic sprayers work best at a spray distance of less than 6 m.

Air-assisted sprayers appear to perform significantly better than those without air assistance. These sprayers use less spray volume, about 100 L/ha, than HV equipment. Pesticides are mixed with water and both liquids and wettable powders can be applied. Sprays are applied by hand. Research has demonstrated that good deposition and distribution is provided, even on the undersides of leaves.

Advantages of ULV and LV applicators

- Greater target efficacy in open structure crops.
- Use less water or oil to dilute the chemical.
- Take less time to apply; ULV can be applied overnight, and by remote control.
- Produce most of the spray volume in small, often uniformly sized droplets; LV less than 100 microns in diameter, ULV less than 30 microns in diameter.
- Plants are generally drier after LV and ULV sprays than after HV sprays.
- Cover more surface area over greater distances.

Disadvantages of ULV and LV applicators

- Only suited to fully enclosed structures.
- Entry into structure prohibited for prolonged period.
- Require specialised breathing apparatus in addition to normal protective clothing to prevent inhalation of small droplets and skin contact.

- Ultra-low volume not suited to structures that cannot be sealed.
- May leave pockets of untreated plants in corners of the greenhouse.
- May not give adequate underleaf coverage in dense foliar canopy.
- Plants closest to the sprayer often have heavier deposition.
- Not suited to spot treatment, or for pesticides requiring spray to run-off, for example oils, soaps.

Smoke generators

Smoke generators are popular overseas, but little used in Australia. Only one smoke-formulated chemical, permethrin (Imperator Smoke Generator®) is registered in all States for use against aphids and caterpillars infesting ornamentals in greenhouses.

Space-release applicators usually perform best if air movement is controlled in the greenhouse. The greenhouse must be sealed or smoke should be used during still conditions. Phytotoxicity may occur if plant surfaces are moist and there is poor air movement; both cause chemical to concentrate in certain areas. A smoke canister is loaded to treat a certain area and after circulation the fans are switched off to let the chemical settle.

Disadvantages of smoke generators

- Require specialised breathing apparatus to prevent inhalation of small droplets.
- Not suited to structures that cannot be sealed.
- May leave pockets of untreated plants in corners of the greenhouse.
- Not suitable for spot treatment or small greenhouses.
- May not give adequate under-leaf coverage in dense foliar canopy.
- May cause phytotoxicity in some circumstances.

Management of spray drift

Spray drift is a significant problem for many urban ornamental plant producers. Reducing spray drift ensures better value for money spent on pest control, protects the environment and prevents unnecessary worker and public exposure to pesticides. Spray application should not impact on neighbours, and this may limit the choice of application method and chemicals.

> *It is the responsibility of the person applying a pesticide to do all things necessary to avoid spray drift onto adjoining land or waterways.*

There are three ways to manage spray drift:

- **Control droplet size.** Increasing droplet size decreases drift but this may conflict with the need for efficacy.
- **Use buffer zones.** The establishment of tree belts will minimise the chances of spray drift spreading from your property to neighbouring areas, including residential developments. Screening buffers or separate production areas may be used to minimise the risk of chemical spray contacting non-target plants.
- **Assess prevailing wind speed and direction.** Do not spray unless weather conditions provide low risk of drift to non-target areas.
- **Use wick applicators** to apply post-emergence herbicides near sensitive crops.

Management of pesticide residues

Clean interior surfaces of plastic and glass covers in greenhouses with high phosphate detergent or soap washes to remove chemical residues that may be harmful to biocontrol agents. Plastic pots may also absorb pesticides and should be soaked in bleach or detergent. Residues can seriously impact on establishment of natural enemies.

Set aside an area where spray application equipment can be cleaned after use and contaminated wastewater contained. Do not allow ground water contamination or run-off into waterways. Consider the use of properly signed run-off filtration ponds on your property.

Pesticide recommendations

What is a biorational chemical?

Biorational, also referred to as '*reduced-risk*' or '*soft*', is a term that is appearing more often in the literature and deserves some explanation. Incidentally, not everyone likes the 'biorational' or 'soft' terminology.

The term refers to chemicals that are considered ecologically sustainable. Biorational chemicals usually have low mammalian toxicity, making them relatively safe to workers. They possess no or limited threat to non-target organisms, making them potentially compatible with biocontrol agents. These chemcials may possess unique modes of action and have short residual presence on leaf surfaces.

In the USA, the passage of the Food Quality Protection Act 1996 enabled reduced-risk chemicals to be fast-tracked through the registration process.

Many agrochemical companies developing new pesticides are aware of the benefits of chemicals that fall within this classification. The term is somewhat subjective in that there isn't a protocol that qualifies some chemicals and not others, at least in Australia.

Which pesticides may I use?

All chemicals used on your crops under ordinary situations (other than emergencies requiring off-label use) must be registered for your crop, and for the particular pest you are targeting. A pesticide label is a legal document and must be followed at all times. The National Registration Authority (NRA) assesses and registers agricultural chemical products. It is an offence to advertise, recommend or use non-registered products. Check with the Farm Chemicals Program Coordinator in your state department of agriculture if in doubt. All registered products should have a registration number on the label.

The chemical information contained in this information guide is based on knowledge and understanding at the time of writing (March 2000). However, because of advances in knowledge, users should contact their State department of agriculture, or their independent adviser for the latest information.

more info

The Nursery Papers
1999#09
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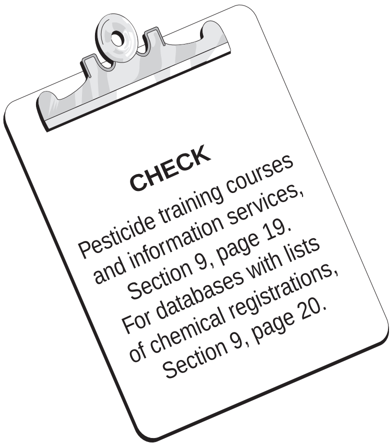


Handy Guide 4, Chemicals currently registered for common pests of ornamentals and *Handy Guide 5, Chemicals currently registered for common diseases of ornamentals* in the front of this information guide, list chemicals registered at March 2000. However, we strongly advise you to seek your own list of registered chemicals.

Information listing registered products is available from several sources. Remember that State requirements may differ.

Your local supplier of agricultural chemicals can also help you. These companies usually have experienced staff who can advise on products for pest and disease control. Their advice should be restricted to registered products.

What are off-label permits and trial permits?

Permits issued for emergency or minor uses are known as *off-label permits*. Permits issued for research trials are called *trial permits*. These permits legalise use of unregistered products and unapproved use of registered products for a limited period and for specific purposes.

- An *emergency* is defined as an outbreak of an exotic pest or disease for which no registered product exists.
- *Minor use* refers to the use of a product on a crop or animal grown on a small scale.
- *Research trials* can involve unregistered products to generate data for registration.

> *Some of the chemicals quoted in this information guide are approved under permits issued by the National Registration Authority (NRA) and in force at the time the publication was prepared. Persons wishing to use a chemical in a manner approved under permit should obtain a copy of the relevant permit from the NRA and must read all the details, conditions and limitations relevant to that permit, and must comply with the details, conditions and limitations before use.*

For general information on NRA off-label permits, phone the NRA on (02) 6271 6347. Information on who can apply for a permit and other relevant matters can be found in the NRA Internet site: http://www.dpie.gov.au/nra/minor.use.html (and hit 'apply').

State laws can vary in relation to off-label permits. Most Australian States require off-label permits for the use of any chemicals not registered for a particular crop and pest. In Victoria it is possible to use a registered agricultural chemical off-label without a permit, but the user will be responsible for such use. No off-label use is allowed for Schedule 7 chemicals and other restricted chemicals. A permit issued in Victoria is required for off-label use of these chemicals. Use at higher than label rates or more frequently than stated on the label requires a permit from the NRA.

Are there any courses on chemical use?

From the year 2000, farm chemical user courses will be nationally registered as ChemCert across Australia. Previously, different States have had varying names such as ChemSmart in Queensland, Farm Chemical Users Course in Victoria and FarmCare in other States.

ChemCert courses are accredited and will provide participants with a certificate upon successful completion. The courses follow similar topics and are held on demand throughout the year in all States and Territories except the ACT. Courses last from one to four days, and participants are encouraged to update their knowledge every five years with a four to six hour refresher course, which provides ChemCert re-accreditation.

ChemCert courses cover:

- Pests and pest management
- Understanding farm chemicals
- Selecting chemicals: reading the label
- Transporting and storing chemicals
- Preparing farm chemicals
- Applying chemicals, calibrating equipment
- Cleaning up and disposing of chemicals
- Emergency procedures and poisoning
- Personnel Protective Equipment (PPE)
- Planning chemical use.

Across Australia, more than 130 000 people had completed the ChemCert course by the end of 1999. Anyone who handles agricultural chemicals should attend a ChemCert course to ensure their own safety and that of other people and the environment.

Phone the ChemCert organiser in your State for more information:

Queensland	Ph: (07) 3352 5033; Fax: (07) 3352 5042
New South Wales	Ph: (02) 9387 4714; Fax: (02) 9387 4746
Victoria	Ph: (03) 5622 2055; Fax: (03) 5622 2199
Tasmania	Ph: (03) 6331 2131; Fax: (03) 6331 4344
South Australia	Ph: (08) 8226 1842; Fax: (08) 8226 1844
Western Australia	Ph: (08) 9341 5325; Fax: (08) 9341 5325
Northern Territory	Ph: (08) 8946 6328; Fax: (08) 8946 6690

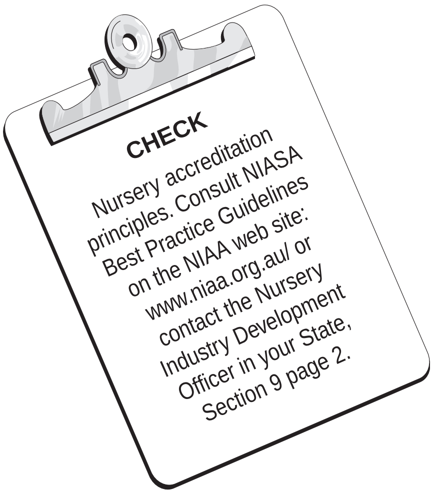
Maximising the success of IPM

To help you start IPM on your property and to increase the success rate, review these key points:

- Revisit the site assessment issues to see how you can minimise the risk of pest and disease outbreaks on your property. They are all relevant.
- Take a look at your plant suppliers. Material coming in 'dirty' disadvantages you from the first day. There is no excuse for infested propagation material. For nursery producers, deal with NIASA accredited suppliers if possible. If NIASA suppliers are not available, inspect suppliers' facilities and request changes if you are not satisfied. If you use biocontrol

agents, you may need an agreement with your suppliers on which pesticides are applied before delivery to avoid harmful residues.

- In greenhouses, consider installing insect-proof screening over vents and open sidewalls, and/or installing double entry doorways with positive air pressure to keep out pests. This is particularly important where virus transmission is high and pest tolerance is very low.
- Practise crop management. Avoid growing susceptible varieties. Keep plants with similar problems together so they can be monitored more closely and spot treated.
- Invest in structures and equipment that put you in control of environmental conditions. Plan new greenhouses to properly address environmental issues and pest management principles.
- Modify the greenhouse environment. Monitor temperature and humidity to minimise the risk of disease initiation and spread, and slow down the rate of development of insect pests. For example, install shading screens or evaporative cooling such as a fan-pad system.



- Install fogging systems for cooling and to provide optimum humidity to favour both plants and beneficials.
- Adversely influence the behaviour or establishment of insect pests through the use of specialty films for greenhouse covers.
- Ensure effective ventilation through adequate and appropriately designed vent areas, plus forced-air fans for additional ventilation.
- Avoid crop wetness, for example by using anti-drip plastic covers and controlling relative humidity, and by using subirrigation or ground-based watering systems.
- Improve drainage to avoid standing water and algal growth.
- Have key pesticides on hand to avoid delays that turn a spot treatment into a broad cover application.
- Be familiar with suppliers of biocontrol agents, their product range, and any necessary lead-in times. A seasonal or crop-long arrangement lets both parties plan ahead.
- Have a clear understanding of what action will be taken, by whom, under any program and under any eventuality.
- Be aware of site hygiene practices.