Nursery Pesticide Application
Best Practice Manual

September 2013

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INTRODUCTION

The nursery industry in Australia is very diverse, with enterprises ranging from small, owner-operator ventures to large, multi-million-dollar corporate businesses. A wide range of plant types is grown, from immature seedlings through to fully mature trees. Some production occurs in glasshouses and shade houses, while in other cases, stock is grown in open plan production areas. It is in this range of environments that pesticides need to be efficiently and safely applied for the management of pests (insects, pathogens and weeds).

The management of pests is an important part of nursery operations. A wide range of pest management measures is available, including chemical, biological, varietal and mechanical measures. All available control methods should be considered before a chemical option is employed within an Integrated Pest Management (IPM) program. The purpose of this manual is to provide information on the effective and safe application of pesticides as part of an IPM strategy for plant nurseries.

The right spray equipment, when correctly used within a well-considered pest management program, is a critical factor in ensuring the success of that program. However, consideration must be given to the type of pest, the pesticide’s mode of action and the environment in which the pesticide needs to be applied. In nurseries, special consideration should be given to the production environment, the influence of shade structures and irrigation systems and the proximity of neighbours and the workforce.

A note on legal usage of chemicals

This manual does not consider or discuss the registration status or legal usage of specific chemicals, or their active constituents, as it is the legal obligation of the nursery operator to abide by the national and local approved registrations.

Currently in Australia (excluding Victoria) if the specific crop and cropping system (e.g. nursery stock, non-food) is not registered on the label it is illegal to use that product unless a ‘Minor Use’ or ‘Emergency’ permit has been issued by Australian Pesticides and Veterinary Medicines Authority (APVMA). It is illegal to use a pesticide, with the same active constituent as a product that is registered, if that pesticide does not have a label registration or an APVMA permit.

Minor Use Permits allow industries that apply small volumes of pesticide to legally access the product when the manufacturer or importer decides not to register the pesticide for that specific crop or cropping system. The nursery industry is currently leading a Minor Use Pesticide program for pesticides, funded via the Nursery Products Levy, to secure access to priority pesticides.1


Best management practice for pesticide application in the nursery industry

What is best practice?

Best practice in any industry is usually described as a process of continual improvement in how operations are carried out. In the area of pesticide application this means that individuals and organisations need to assess how appropriate their current operations are and put into place plans and programs that continuously improve those operations.

What is this manual designed to do?

This manual is designed to assist nursery operators in identifying and understanding the range of pesticide application equipment available and the key issues related to the use of pesticides in the nursery environment.

To assist the nursery industry in improving the safe and effective application of pesticides, this manual includes information on:

- developing spray management plans
- the types of pesticides available and their storage, handling and disposal
• the risks various pesticides may present and the selection and use of personal protective equipment to manage these risks
• suitable operating conditions for pesticide application and managing spray drift
• the advantages and disadvantages of various types of pesticide application equipment
• the calibration of pesticide application equipment
• case studies detailing examples of industry practice and critical comments
• useful contacts and references.

How to use this manual
Each section of the manual provides information on the range of products and techniques available to nursery operators for the application of pesticides. Best management practice is a process of continual improvement. This manual enables users to examine their practices with a view to improving the safe and effective use of pesticides in their situation.

Due to the diverse nature of the nursery industry, frequent changes in legislation and the development of new application equipment, it is impossible to provide examples of best practice for all the types of spraying operations that are likely to occur. This manual contains background information that individual nurseries should consider so that they can develop and improve their current practice.

Throughout the various sections of the manual, the advantages and disadvantages of a range of products and techniques are discussed. It is the responsibility of the user to determine which of these products and techniques may lead to improvement in the safe use of pesticides.

The following key is used within this manual to indicate sprayer type, droplet size, pesticide type, nursery design, expected coverage and nursery size that may be suitable for each type of application equipment discussed.

Key to symbols used in this manual

Sprayer type

- Ultra low volume
- Low volume
- High volume

Droplet size

- Fine and very fine
- Medium
- Coarse

Coverage

- Spot spray
- Blanket spray

Pesticides

- Fungicides
- Herbicides
- Insecticides

Nursery design

- Open plan
- Shade house
- Glasshouse

Nursery size

- Small
- Medium
- Large
Requirements for best management practice in pesticide application

Best practice in the selection and use of pesticides begins with the correct identification of the TARGET and then the development of a pest management program, which may include the use of pesticides. If a pesticide is to be used, it must be applied to the right PLACE at the right TIME with minimal impact on people, beneficial organisms, property and the environment.

Nursery operators should ask themselves a series of questions before commencing any pest management program. These include:

1) Has the target been identified correctly?
Before proceeding with the use of any pesticide it is essential to determine the biological target. For example, different application techniques may be required to manage insect pests, weeds or plant pathogens.

2) Has the most appropriate method or methods of pest management been chosen?
As part of an Integrated Pest Management (IPM) regime a number of methods are available to the nursery operator. Issues such as cost, safety, effectiveness and chemical resistance of insects should be considered before chemical control is employed. Other methods include:
- mechanical—pruning, hand weeding, hoeing
- cultural—hygiene strategies, controlled environments, insect meshes
- biological—beneficial insects, predator releases, companion planting
- genetic—pest and disease resistant cultivars
- quarantine—use of exclusion areas, plant movement restrictions
- chemical—herbicide, fungicide, insecticides

There may be a number of pesticides registered for the management of a single pest in various industries or locations. Only products that are registered for the particular situation should be used.

When selecting a pesticide operators must consider:
- the susceptibility of the target pest
- the susceptibility of non-target organisms
- the stability of the product (e.g. whether the chemical is quickly broken down or has an ongoing or residual activity)
- the cost of the pesticide and the cost of application
- the type of formulation and safety issues
- the logistics (ease of transport, handling and storage)
- the availability of the product of choice
- the shelf life of the product.

3) Is the right amount being applied?
The correct dose of pesticide should, in most situations, be uniformly distributed across the area to be treated. This can be achieved by using an appropriate application technique with accurately calibrated equipment. Pesticides should always be applied at the rate specified on the product label. The label is a legal document, and the label information on usage conditions and other directions must be followed.

4) Is the product being applied to the right place?
It is common for pesticides to be applied to only a portion of a nursery rather than the entire area. It is important that these areas are readily identifiable so that the pesticide is applied at the correct location and accurate records of use can be kept.

5) What is the best time to apply the product?
If the product is not applied at the right time the treatment may be ineffective. Factors that influence the timing of application include:
- the lifecycle of the pest*
- the meteorological conditions
- other activities that are occurring in the area
- staff and bystander locations and re-entry periods.

*Many products are most effective at certain stages of the pest lifecycle or stage of plant growth. For example, many insect pests are only susceptible to certain products during their immature (larval or nymphal) stages. Similarly many weed species will only be affected by some herbicides while they are small, actively growing and not experiencing stress.

6) Is the appropriate personal protective equipment (PPE) being used?
Operators should consult the product label and the Safety Data Sheet (SDS), previously referred to as MSDS or Material Safety Data Sheet, before proceeding with any operation, to determine what PPE is required when mixing and applying the chosen product.
An understanding of the principles of safe mixing, loading and use of pesticides is required. Carrying out a risk assessment will assist in the identification of hazards and the management of risks.

7) Was the desired outcome achieved?
After every application, after the re-entry period has expired, assess how well the product performed. Record this information and keep it for future reference, along with the data gathered that led to the decision to use the pesticide treatment.

8) Were there any unexpected outcomes?
Were there any detrimental effects on workers or adjacent areas? If so, were these recorded and how may they be minimised in the future?

Using this information to implement best management practice in pesticide application
All of the previous questions should be asked prior to, during and after each pesticide application. By asking these questions, recording the results and using the information contained in this manual, the practices and procedures that can assist in moving towards best management practice in pesticide application can be implemented.
CHAPTER 1.

SPRAY MANAGEMENT PLANS

All nursery operations should have a spray management plan, including a risk assessment. Chemical users should be aware (or be made aware) of the risks associated with chemical application. A generally accepted risk assessment process has been established for effectively managing risks.

The process is:
1. Identify the hazard.
2. Assess the level of risk.
3. Control the risk.
4. Review.

Generic risk assessment templates and policies are available online or through your state workplace health and safety department (refer to the contact details on page 84). These should form part of a ‘Spray Management Plan’ covering areas such as spray operator training, managing other nursery staff so that they do not come into contact with contaminated stock or spray drift, timing of applications, record keeping and emergency procedures.

1.1 Training

All spray operators involved in the application of nursery chemicals should be qualified according to relevant state training and accreditation requirements. For example, all spray operators should have completed a farm chemical users course (e.g. ChemCert) or other equivalent recognised chemical application course (refer to the contact details on page 84). Employers have legal responsibilities to ensure that their employees are correctly trained in the use of chemicals and related equipment and ensure they are aware of, and adhere to, the record keeping requirements.

1.2 Time of application

Pesticides are most effective when they are applied at the right time. Pests are most effectively managed with pesticides when they are small or just starting to develop rather than when they are more mature. Plants should be monitored or checked regularly for pests (insects, plant pathogens and weeds) so that pest management activities can be performed at the right time.

Another factor to consider when deciding when to spray is the presence of other nursery staff, clients or members of the public. In general, it is best to arrange spraying operations so they are undertaken at times when no one else is around, such as after closing time or on the weekends.

Weather conditions before, during and after application can all influence the timing of the spray application. Chapter 3 discusses in detail the influence of weather conditions on the likelihood of spray drift and these factors should be considered while deciding when to spray.

In general, pesticides should not be applied to plants that are stressed due to weather conditions. For example, avoid the application of pesticides during the hottest part of a summer day or if a frost is present.

1.3 Record keeping

Spray operators need to keep accurate records of all spraying activities. This should be part of any quality control strategy and is required under state and federal legislation. It is also mandatory for compliance with codes of practice covering workplace health and safety.

The spray operator should maintain up-to-date records of pesticide usage and spray operations. The operator should complete a spray report after every spray operation. The report should include the date, time, area sprayed, amount and type of pesticides applied, recorded application rates, crop details, pests present, operator(s) involved, equipment used, nozzle type, settings (e.g. spray pressure) and meteorological conditions (wind speed and direction, temperature and humidity).

Maintaining accurate records of all pesticides used at the nursery site will assist the manager in making informed management decisions.
The information recorded must include:
- calibration data, including specific nozzle information (type, pressure of operation/rotation speed etc)
- registered pesticide used, and the amount used
- personal protective equipment used and maintenance details of PPE
- environmental conditions
- area sprayed (location and size)
- pest/crop description.

Table 1 is a sample checklist for spraying operations. Another example of a recording system is the Nursery & Garden Industry Australia (NGIA) Pesticide Usage Form (figure 1). This is an electronic form that allows the creation of a coding system for your nursery spray operations. For example, a shade house might be referred to as Area 1 and a glasshouse as Area 2. You can produce a code for particular operations, e.g. spraying could be S1 and mixing M1.

Figure 1. Nursery & Garden Industry Australia (NGIA) Spray Diary Recording Sheet

* You can develop a unique code for these data fields to identify an area, crop or target pest. Alternatively, enter the full details.
** You can use a code from those provided on the right hand side of this recording sheet.
Table 1. Sample operational plan – overview checklist

<table>
<thead>
<tr>
<th>Task</th>
<th>Tick</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PLANNING – PRE SPRAY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical user</td>
<td>Joe Bloggs</td>
<td></td>
</tr>
<tr>
<td>Field owner</td>
<td>Fred Bloggs</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>√</td>
<td>6 km SE of Country Town</td>
</tr>
<tr>
<td>Area to be sprayed, area (hectares) and type</td>
<td>√</td>
<td>Bedding plants</td>
</tr>
<tr>
<td><strong>Nature of pest problem</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are there any alternative methods to spraying?</td>
<td>√</td>
<td>No</td>
</tr>
<tr>
<td>Consult an up-to-date Awareness Zone Chart</td>
<td>√</td>
<td>Yes</td>
</tr>
<tr>
<td>Sensitive areas within Awareness Zone</td>
<td>√</td>
<td>Vineyard 1 km</td>
</tr>
<tr>
<td>Communicate to neighbours</td>
<td>√</td>
<td>Yes, by phone 5/7/13</td>
</tr>
<tr>
<td>Check user training credentials</td>
<td>√</td>
<td>ChemCert® 15/12/12</td>
</tr>
<tr>
<td><strong>APPLICATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment in proper working order and calibrated</td>
<td>√</td>
<td>Leak repaired</td>
</tr>
<tr>
<td>Spray equipment</td>
<td>√</td>
<td>Hand gun</td>
</tr>
<tr>
<td>Nozzle type</td>
<td>Dg 110-03</td>
<td></td>
</tr>
<tr>
<td>Nozzle number</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Droplet size</td>
<td>BCPC medium</td>
<td></td>
</tr>
<tr>
<td><strong>Settings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray pressure (bar)</td>
<td>√</td>
<td>2 bar</td>
</tr>
<tr>
<td>Product label and SDS read and understood</td>
<td>√</td>
<td>Yes</td>
</tr>
<tr>
<td>Check wind direction is away from susceptible areas</td>
<td>√</td>
<td>Yes</td>
</tr>
<tr>
<td>Wind direction in °</td>
<td>√</td>
<td>From NE 040°</td>
</tr>
<tr>
<td>Windspeed in k/hr</td>
<td>√</td>
<td>10 k/hr</td>
</tr>
<tr>
<td>Temperature in °C</td>
<td>√</td>
<td>27 °C</td>
</tr>
<tr>
<td>Relative humidity %</td>
<td>√</td>
<td>50%</td>
</tr>
<tr>
<td>Cloud cover in eighths</td>
<td>2/8</td>
<td></td>
</tr>
<tr>
<td>Approximate stability class (unstable, neutral or stable)</td>
<td>Neutral</td>
<td></td>
</tr>
<tr>
<td>Is a ground surface temperature inversion present?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Are weather parameters within acceptable limits?</td>
<td>√</td>
<td>Yes</td>
</tr>
<tr>
<td>Are you wearing correct PPE for the job?</td>
<td>√</td>
<td>Yes</td>
</tr>
<tr>
<td>Date</td>
<td>13/4/2013</td>
<td></td>
</tr>
<tr>
<td>Time start of spraying</td>
<td>10.00 hr</td>
<td></td>
</tr>
<tr>
<td>Time end of spraying</td>
<td>16.00 hr</td>
<td></td>
</tr>
<tr>
<td>Chemical type(s)</td>
<td>2.5 L/ha</td>
<td></td>
</tr>
<tr>
<td>Product application rate (L/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk volume rate (L/ha)</td>
<td>√</td>
<td>50 L/ha</td>
</tr>
<tr>
<td>Amount of product used</td>
<td>35 L</td>
<td></td>
</tr>
<tr>
<td>Treated area (ha)</td>
<td>0.2 ha</td>
<td></td>
</tr>
<tr>
<td>Is crop/other buffer used?</td>
<td>√</td>
<td>30 m boundary</td>
</tr>
<tr>
<td><strong>POST SPRAY EVALUATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Were results satisfactory? (note numbers controlled/escaped)</td>
<td>√</td>
<td>Yes</td>
</tr>
<tr>
<td>Could there be any improvements?</td>
<td>√</td>
<td>No</td>
</tr>
<tr>
<td>All spray records correct, up-to-date and stored safely?</td>
<td>√</td>
<td>Yes</td>
</tr>
<tr>
<td>Full name of chemical user</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.4 Emergency procedures

There are a number of hazards that exist when using registered pesticides. These can include fires, spills and poisoning. It is important that the nursery has emergency procedures in place to respond to any incident. It is also important to evaluate current practice to avoid an emergency situation. The following section discusses the areas that should be covered in planning and dealing with emergencies.

A plan for handling emergencies such as spills, accidental contamination of people and the environment should be developed as part of a risk assessment related to the use of pesticides in the nursery. Completion of a ‘Managing farm safety’ course will assist in understanding and carrying out a risk assessment. This knowledge can then be used to manage hazards.

Both the EcoHort Nursery Industry Environmental Management System and the current AgSafe® Accreditation Training Manual (2002) contain detailed information on emergency procedures related to pesticide storage and handling.

Fires

Prevention of fires must be a primary consideration when organising the storage of products on the nursery site. Incompatible products such as flammable chemicals, oxidants and corrosive products should not be stored next to each other.

A fire management plan may include the following points:
1. Raise the alarm and evacuate the premises.
2. Notify the fire brigade and police.
3. If it is safe to do so, start fire-fighting operations with on-site equipment suitable for the purpose (e.g. handheld fire extinguishers). Wear protective clothing.
4. Check that the fire-water and spilt product is being contained.
5. If run-off occurs or there is a danger of exploding containers, consider withdrawing and allowing the fire to burn out.
6. Any person experiencing side effects from fire (e.g. dizziness) should be placed under medical care.
7. Remove contaminated clothing. On completion of activities, equipment and all clothing should be cleaned and a shower taken by all personnel involved.

Spills

The guiding principles in clean-up operations following an accidental spill are:
1. Isolate the affected area.
2. Wear appropriate personal protective equipment (PPE) as recommended on the label.
3. Contain the spilled chemical and prevent further contamination.
4. Decontaminate the affected area with a suitable absorbing medium or other appropriate means (refer to the SDS).
5. Dispose of the spill by safely packing the absorbing medium into proper containers.

In the event of a major spill incident call ‘000’.

At each chemical storage area, a ‘spill response equipment kit’ suitable for the purpose should be maintained. A basic kit to deal with spillage should be kept at the mixing and measuring site. A spillage kit should consist of:
- sand or soil, kitty litter or vermiculite
- hydrated lime (several bags)
- square-mouthed shovel(s)
- open drums (20 L and 200 L) to collect materials
- bleach (hypochlorite) (20 L drum)
- funnels, a broom, banister brush and pan
- PPE suitable for handling concentrates, including eye protection, gloves, respirator and disposable foot protection.

Emergency numbers must be clearly displayed at the sites of storage, handling and mixing. If a person has been injured or requires medical attention as a result of the spill some states require the incident to be reported.

Poisoning
Rapid response is essential in all cases of poisoning. The speedy removal of the source of contamination and rapid first aid implementation and transport to hospital or a doctor may save a life. For information on first aid, read the appropriate label and SDS (see figures 3 and 4 for examples).

Do not substitute first aid for professional treatment. First aid is only to relieve the patient before medical help is reached. Check for danger to yourself before first aid is attempted.

If a person who has been in direct contact with a pesticide shows signs of poisoning, take the following steps:
1. Stop any further exposure to the poison by moving the patient away from the contaminated area and from the vicinity of agricultural and veterinary chemicals. Quickly remove any contaminated clothing and wash skin.
2. Begin first aid immediately. See product label for instructions.
3. Call a doctor as quickly as possible but do not abandon the first aid treatment.
4. Keep the patient as quiet as possible and complete the first aid treatment.
5. Keep patient warm and comfortable.

The national Poisons Information Hotline is 13 11 26.
The selection of chemicals and their proper storage, handling and disposal is critical to operator safety and protection of other people and the environment.

2.1 Labels

The pesticide label is a legally-binding document that has been approved by the Australian Pesticides and Veterinary Medicines Authority (APVMA), formerly known as the National Registration Authority (NRA). It provides sufficient information to allow the safe and efficient use of the pesticide, provided the directions are followed carefully (figures 2 and 3).

The label lay-out is largely dictated by regulation and will depend on the size of the pack and the amount of information required to be provided. A minimal design would be a main panel plus an ancillary panel, but there may be two ancillary panels. If this format provides inadequate space, some information can be printed on a leaflet attached to the container, in which case the leaflet is part of the label.

First and foremost the spray operator must read, understand and adhere to the pesticide product label prior to any spraying operation.
Section A
1. The signal heading
2. Brand name (or trade name)
3. Type of chemical
4. Active constituent
5. Resistance group
6. What the chemical does
7. Name, address and phone number of the business that made the chemical

Section B—Directions of use
8. Restraints
9. Directions for use table
10. NOT TO BE USED FOR... statement
11. Withholding period (WHP)

Section C—General instructions
12. Resistance warning
13. Compatibility
14. Mixing instructions
15. APVMA compliance instructions for mandatory droplet size categories

Section D—Precautions
16. Re-entry period
17. Plant-back period
18. Protection of crops, native and other non-target plants
19. Protection of livestock
20. Protection of wildlife, fish, crustaceans and the environment

Section E
21. Storage and disposal
22. Safety directions
23. First aid
24. APVMA approval number
25. Batch number, date of manufacture (DOM) and expiry date
26. Dangerous goods/hazardous chemical information
Confidor 200 SC Application

- Apply the minimum spray volume of 25 L/ha. A sprayer VMD of 100 - 110 mls/m must be used. Do not exceed this charge rate for Confidor. Confidor should not be applied using lower volume sprayer systems. The use of large drop size equipment is not recommended.

- Ensure even application

- Dilute Spraying

- Set up and operate the sprayer to achieve even coverage throughout the crop canopy. Ensure sufficient water to cover the spray swath width or exceed a swath width of 20 to 22 m. Do not apply Confidor plus Pulse using Ultra Low Volume (ULV) apply rates. Do not apply in high density aphid colonies (hotspots) on the same total amount of product. Do not apply Confidor plus Pulse or equivalent if there is rapid crop growth; or if existing high density aphid colonies (hotspots) are suspected. Factor in recommended swath width for the performance of Confidor. Apply early in the season.

- The addition of Pulse Penetrant or equivalent is critical for loss or damage arising from failure to follow such directions and instructions. Refer to the relevant material. So far as it is lawfully able to do so, Bayer CropScience Pty Ltd accepts no liability or responsibility for the performance of Confidor in any crop. The label rate is 3 sprays 2 weeks apart. Do not use in equipment that requires rates of water lower (i.e. no more than 1 or 2 leaves per plant with the same total amount of product to the target crop whether cover spray, ensuring thorough coverage. Apply by spot spraying or as a full spray. The mixture and then water it in well immediately after application. Avoid contact with stock food. DO NOT graze any treated area, or cut for stock food. DO NOT feed produce harvested from treated areas to animals, including poultry.

- Confidor 200 SC Insecticide has been used on a wide range of ornamental plant species without damage. However, some species and cultivars are particularly sensitive to chemical sprays and it is the related to local conditions. It is advisable to treat only a small number of plants first, in order to ascertain their reaction before treating the whole crop. DO NOT graze any treated area, or cut for stock food. DO NOT feed produce harvested from treated areas to animals, including poultry.

- DO NOT allow run-off from treatment areas to enter drains and waterways.

- Do not store in prolonged periods in direct sunlight.

- If spraying is postponed, the spray application should be delayed until the next available opportunity to spray.

- If spraying is postponed, the spray application should be delayed until the next available opportunity to spray.

- DO NOT graze any treated area, or cut for stock food. DO NOT feed produce harvested from treated areas to animals, including poultry.

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- DO NOT graze any treated area, or cut for stock food. DO NOT feed produce harvested from treated areas to animals, including poultry.

- **Déjà vu**

**FOUR-STEP SAFETY GUIDELINES FOR EMERGENCY ONLY**

**PHONE 1800 555 111**

**DIRECTIONS FOR USE**

**FOLIAR SPRAY APPLICATIONS**

**RATE**

- **Preventive**
  - 25 mL/100 L
- **Curative**
  - 50 mL/100 L

**MATERIAL SAFETY DATA SHEET**

- Additional information is stored in the Material Safety Data Sheet, which can be obtained from www.bayercropscience.com.au

**FIRST AID**

- In the event of eye or skin exposure, wash with plenty of water for at least 15 minutes. Seek immediate medical attention.

- When removal is necessary, wash contact areas with soap and water. For removal of confidor from skin, wash area with soap and water for at least 15 minutes. Keep area covered and observe for any reaction.

- In the event of eye or skin exposure, wash with plenty of water for at least 15 minutes. Seek immediate medical attention.

- Do not allow run-off from treatment areas to enter drains and waterways.

- DO NOT graze any treated area, or cut for stock food. DO NOT feed produce harvested from treated areas to animals, including poultry.

- DO NOT graze any treated area, or cut for stock food. DO NOT feed produce harvested from treated areas to animals, including poultry.

- DO NOT graze any treated area, or cut for stock food. DO NOT feed produce harvested from treated areas to animals, including poultry.

- **Déjà vu**
### Confidor 200 SC

#### SEEDLING DRENCH APPLICATIONS

<table>
<thead>
<tr>
<th>CROP</th>
<th>PEST</th>
<th>RATE</th>
<th>WHP</th>
<th>CRITICAL COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rape, canola, mustard, brassica</td>
<td>aphid</td>
<td>12.5 mL/1000 plants/ha</td>
<td>150,000</td>
<td>Apply to the transplant cell, once only, prior to transplanting. For applications specifically against green peach aphid and scale insects, select the data linking the insecticide’s crop group to the anticipated degree of pest infestation and previous pest experience (a combination of crop variety, previous year, predator activity, soil type).</td>
</tr>
<tr>
<td>Radicchio, endive, lettuce (excluding head lettuce)</td>
<td>aphid</td>
<td>12.5 mL/1000 plants/ha</td>
<td>150,000 to 110,000</td>
<td>Apply to the transplant cell, once only, prior to transplanting. The maximum recommended application rate per 1000 seedlings will depend on the proposed planting density, as shown in the RATE column, identify the desired planting density and the corresponding recommended rate range.</td>
</tr>
<tr>
<td></td>
<td>Green peach aphid</td>
<td>20-40 mL/1000 plants/ha</td>
<td>150,000</td>
<td>Apply to the transplant cell, once only, prior to transplanting. For applications specifically against green peach aphid and scale insects, select the data linking the insecticide’s crop group to the anticipated degree of pest infestation and previous pest experience (a combination of crop variety, previous year, predator activity, soil type).</td>
</tr>
<tr>
<td></td>
<td>Silverleaf whitefly</td>
<td>40 mL/1000 plants/ha</td>
<td>70,000 to 40,000</td>
<td>Apply to the transplant cell, once only, prior to transplanting. For applications specifically against silverleaf whitefly, including type B, control of green peach aphid, and scale insects, select the data linking the insecticide’s crop group to the anticipated degree of pest infestation and previous pest experience (a combination of crop variety, previous year, predator activity, soil type).</td>
</tr>
</tbody>
</table>

#### WITHHOLDING PERIODS

- **DO NOT transplant seedlings treated by seedling drench into hydroponic production systems.**

#### Critical Comments

- **Confidor 200 SC**
- **Continued from previous page**
- **Continued**
- **NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION**

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**September 2013 13**

Figure 3. Sample pesticide label (courtesy of Bayer CropScience Pty Ltd) (continued)
For an SDS to be useful three things need to happen:
1. The SDS should be read and understood before an emergency.
2. The SDS must refer to the actual pesticide formulation being used.
3. The SDS must be current and easily available to the applicator.

An SDS for each product being stored or used should be available for staff to read and copies kept in or adjacent to the pesticide storage area.

Safety data sheet (SDS)

Previously referred to as an MSDS or Material Safety Data Sheet, a Safety Data Sheet (SDS) contains more detailed information about the nature of the product and how to respond if there is an emergency. An example of an SDS is provided in figure 4.

Information in the SDS includes:
- identification details (e.g. product name and physical description/properties)
- health hazards (e.g. health effects and first aid)
- precautions for use (e.g. personal protection and flammability)
- safe handling information (e.g. storage and transport)
- information on toxicity
- information on ecological effects.

A product’s SDS is available on request at the point of sale and is also downloadable from the manufacturer’s website. A current SDS for each product should be made available for users. The SDS is reviewed by Safe Work Australia as part of the chemical registration process and provides useful additional information if an emergency occurs.

Figure 4. Example Safety Data Sheet (SDS) for Confidor® (courtesy of Bayer CropScience Pty Ltd)
**SECTION 13. DISPOSAL CONSIDERATIONS**

- **Metal drums and plastic containers:** Place in a disposal pit specifically marked and set up for this purpose clear of waterways, desirable
- **Additional ecological information:**
  - **Toxic to bees:**
    - Exposure time: 72 h
    - Toxicity to bees.
    - The value mentioned relates to the active ingredient imidacloprid.
  - **Toxic to aquatic invertebrates:**
    - Exposure time: 48 h
    - The value mentioned relates to the active ingredient imidacloprid.
  - **Toxic to aquatic invertebrates:**
    - Exposure time: 24 h
    - The value mentioned relates to the active ingredient imidacloprid.
  - **Toxic to fish:**
    - Exposure time: 96 h
    - Toxicity to fish LC50 (Leuciscus idus (Golden orfe)) 237 mg/l
    - Toxicity to fish LC50 (Cyprinus carpio (Carp)) 280 mg/l
    - Toxicity to fish LC50 (Chironomus riparius (non-biting midge)) 0.0552 mg/l

**SECTION 14. TRANSPORT INFORMATION**

- **IATA:**
  - Class 9
  - Environm. Hazardous Mark YES
  - Subsidiary Risk None
  - Description of the goods: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, Packaging group III
  - Hazchem Code 3Z

- **ADG:**
  - Class 9
  - Description of the goods: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, Packagings group III
  - Hazchem Code 3Z
  - 92/69/EEC, A.14 / OECD 113

**SECTION 15. REGULATORY INFORMATION**

- **Further information:** Further safety related information provided in this SDS and other information is available on request.

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Figure 4. Example Safety Data Sheet (SDS) for Confidor® (courtesy of Bayer CropScience Pty Ltd) (continued)
2.2 Formulations and mixing

When a pesticide is purchased, the product consists of a mixture of components designed to keep it stable until required for use. They may also assist in its ease of handling and final effectiveness. The part that affects target pests is called the ‘active constituent’ and the other additives are called ‘inert constituents’. These may be liquid or dry but together the total mixture is a ‘chemical formulation’. Exact details of formulations are commercially sensitive because they directly influence the cost of manufacture. Formulations vary significantly but, in Australia, they are expected to have a stable shelf life of at least two years.

Types of formulation

Pesticides registered for use in plant nurseries are formulated in a wide variety of ways. It is not unusual to find the same active constituent available in several different formulations, each suited to a particular use and target pest situation. Formulations will vary in the hazards associated with their use, risks to the environment, efficacy in pest management and cost. Where a choice exists, it is best to select the formulation that presents the least risk to the spray operator. The level of risk is noted as the ‘signal heading’ on the label’s central panel (see figure 2). The properties of the active constituent will usually dictate the choice of formulation that can be used to produce a stable, consistent and marketable product.

The simplest way to classify pesticide formulations is whether they are sold as a liquid or a solid. Within each of these two main categories there are a number of different formulation types.

Liquid formulations

Liquid formulations (e.g. Supracide 400) are typically diluted in water to produce the final spray mix, although for some ultra low volume (ULV) applications they may be applied ‘directly from the container’. The amount of formulation added to the sprayer is typically measured using a graduated cylinder or jug. The following are the general types of liquid formulations.

Solutions

These are true liquids, which contain the active constituent dissolved in either water (water-based aqueous concentrates) or a solvent that mixes (is miscible to form a liquid concentrate) with any water that may be added to make up a spray solution. The advantages and disadvantages of the ‘carrier’ solutions will depend on the solvents used, the concentration of the active constituent and the type of application equipment used.

<table>
<thead>
<tr>
<th>Advantages of solutions</th>
<th>Disadvantages of solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• relatively easy to measure, handle, transport and store</td>
<td>• the solvent system used may pose phytotoxic risks under high temperature conditions</td>
</tr>
<tr>
<td>• need little agitation once mixed for application</td>
<td>• the solvent may increase the risk of skin irritation and absorption if accidental operator exposure occurs</td>
</tr>
<tr>
<td>• being liquids, they cause minimal abrasive wear on spray equipment, especially on nozzle orifices</td>
<td>• the solvents may cause equipment deterioration, particularly of washers and seals, which may need frequent replacement to avoid equipment leaks</td>
</tr>
<tr>
<td></td>
<td>• some solvents employed are highly flammable and result in the product being classified as a ‘dangerous good’, with consequent restrictions on how it may be transported and stored</td>
</tr>
</tbody>
</table>
**Emulsifiable concentrates (ECs)**
As the name indicates, ECs contain an emulsifier in the formulation (e.g. Supracide 400®), which enables the active constituent to be dissolved in an organic solvent and then spread evenly through the carrier water when a spray solution is made up. The final spray solution is an emulsion and is usually milky white in colour.

<table>
<thead>
<tr>
<th>Advantages of emulsifiable concentrates</th>
<th>Disadvantages of emulsifiable concentrates</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td></td>
<td>• some solvents employed are highly flammable and result in the product being classified as a ‘dangerous good’, with consequent restrictions on how it may be transported and stored</td>
</tr>
</tbody>
</table>

**Suspension concentrates (SCs) or flowable concentrates**
This type of formulation (e.g. Confidor 200 SC®) was introduced to try and overcome some of the handling problems associated with wettable powders (WPs) or solid formulations. In SCs, the active constituent is milled to a finer size than with WPs and then packed off as a suspension of fine particles within a liquid, which is then further diluted, usually with water as the carrier liquid to make up a spray mixture.

<table>
<thead>
<tr>
<th>Advantages of suspension concentrates</th>
<th>Disadvantages of suspension concentrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>• because of the finer particle size, there is much less chance of nozzle or filter blockages than with WPs</td>
<td>• the suspension may settle out in storage so packs of SCs must always be shaken vigorously before measuring out the dose required</td>
</tr>
<tr>
<td>• there is no dust problem when measuring out</td>
<td>• there is a limit of about 50% in the concentration of active constituent that can be incorporated without causing stability problems in the formulation</td>
</tr>
</tbody>
</table>

**Solid formulations**
Solid formulations may range from fine powders to large granules. They typically require a balance to weigh out the correct amount to add to the spray tank. Some products may come in small pre-weighed packets that can be used as is or have special pre-calibrated mixing cylinders specifically for that formulation.

**Soluble powders**
As the name indicates, this type of formulation dissolves in water to form a true solution (e.g. ProGibb®).

<table>
<thead>
<tr>
<th>Advantages of soluble powders</th>
<th>Disadvantages of soluble powders</th>
</tr>
</thead>
<tbody>
<tr>
<td>• easy to store and transport</td>
<td>• must avoid breathing in the powder when measuring out doses</td>
</tr>
<tr>
<td>• have lower phytotoxicity risks than ECs</td>
<td>• measuring can be difficult unless pre-packs are used</td>
</tr>
<tr>
<td>• can be packed in disposable packages</td>
<td></td>
</tr>
</tbody>
</table>
**Wettable powders**

WPs are designed to be dispersed in water to form a suspension, which is then applied as a spray (e.g. Dithane M-45®). Wettable powders are a convenient way of packing high concentrations of the active constituent (up to 80% of the product) in a stable condition that has commercial appeal. This advantage (to the manufacturer) is outweighed by a number of disadvantages as listed below, which have led to a decline in the popularity of WPs.

<table>
<thead>
<tr>
<th>Advantages of wettable powders</th>
<th>Disadvantages of wettable powders</th>
</tr>
</thead>
<tbody>
<tr>
<td>• a convenient way of packing high concentrations of the active constituent</td>
<td>• constant agitation in the spray vat is needed to avoid uneven dosing caused by particle settlement in the spray vat</td>
</tr>
<tr>
<td></td>
<td>• the suspended particles are abrasive and can cause accelerated wear in nozzles and pumps</td>
</tr>
<tr>
<td></td>
<td>• the suspended solids can block nozzles and filters, particularly if agitation in the spray tank is inadequate</td>
</tr>
<tr>
<td></td>
<td>• many WPs require careful pre-mixing with a little water to ensure even dispersion and this process can be difficult with some alkaline bore waters</td>
</tr>
<tr>
<td></td>
<td>• measuring out by weight can be hazardous unless pre-packs are used and then the pre-packs have to coincide with the dose required per tank of spray</td>
</tr>
</tbody>
</table>

**Water dispersible granules**

This type of formulation is a popular one as newer formulation technologies have produced micro-granules that can carry high concentrations of active constituent (acceptable with low toxicity products, e.g. Simagranz®). The actual concentration put into a particular product will depend on the toxic hazards associated with the active constituent, but concentrations of up to 900 g/kg have been achieved.

<table>
<thead>
<tr>
<th>Advantages of water dispersible granules</th>
<th>Disadvantages of water dispersible granules</th>
</tr>
</thead>
<tbody>
<tr>
<td>• can carry high concentrations of active constituent</td>
<td>• a specific order of mixing may be required when more than one product is to be included in a spray solution</td>
</tr>
<tr>
<td>• avoids the problems of dust generation</td>
<td>• specific weighing or measuring jugs may be required for each product</td>
</tr>
<tr>
<td>• has pour characteristics like a liquid to make measuring easy</td>
<td></td>
</tr>
<tr>
<td>• fine milling of the base ingredients of the formulation prior to actual granule formation ensures no problems with blockages after dispersal takes place in the spray vat</td>
<td></td>
</tr>
<tr>
<td>• the high concentration means that these formulations are more efficient to transport and store</td>
<td></td>
</tr>
</tbody>
</table>
Other formulations

Granules
Free-flowing granular formulations have been used for many years as a means of applying pesticides to manage soil-borne pests or to apply a pesticide in remote areas that depend on rainfall for later activation. Some granules are formulated using a polymer matrix that degrades at a predictable rate, releasing small doses of active constituent over an extended period. These are known as slow or controlled release granules and they were introduced as a means of extending the period of activity for pesticides with shorter active lives. They are a replacement for the long-lasting organochlorines such as DDT and BHC, which were removed from the marketplace in 1987. Granules provide a relatively safe means of handling very toxic pesticides as the formulation involves scattering a small amount of active constituent through a much larger bulk of inert material, usually clay (e.g. SusCon Green®).

<table>
<thead>
<tr>
<th>Advantages of granules</th>
<th>Disadvantages of granules</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ready to use without mixing and are easy to apply</td>
<td>• more expensive than most other formulations because the amount of active constituent incorporated is at a lower concentration</td>
</tr>
<tr>
<td>• application does not involve carrying water, thus reducing soil compression and easier application in hard-to-access areas</td>
<td>• may require soil incorporation or follow-up rain before becoming usefully active</td>
</tr>
<tr>
<td>• usually have little or no dust associated with them and therefore present a low drift hazard</td>
<td>• may present a hazard to non-target species, especially birds</td>
</tr>
<tr>
<td>• the application equipment needed to disperse them is relatively cheap compared with hydraulic sprayers</td>
<td>• not adhering to foliage may be a disadvantage</td>
</tr>
<tr>
<td>• granules can penetrate foliage to reach the soil surface more easily than spray droplets, which can sometimes be an advantage</td>
<td></td>
</tr>
</tbody>
</table>

Aerosol dispensers
These are convenient but are usually expensive. It is difficult to control placement of spray fall-out and this can pose a high risk of inhalation. The formulations often contain a flammable propellant under pressure, which represents a potential hazard if the container is punctured or incinerated (e.g. white oil).

Fumigants
These can be hazardous formulations and many have been phased out of the marketplace. They are toxic to a wide range of organisms and often do not discriminate between pests and beneficial species. They can penetrate target areas very efficiently and usually only involve a single application. Fumigants are extremely hazardous to use and most require special training in safe handling, particularly in regard to the use of appropriate protective equipment. Confining fumigating gases to the desired area of action can sometimes cause problems (e.g. methyl bromide or chloropicrin).

Water soluble crystals
This formulation type is being used for 2, 4-D based products packed in water soluble plastic packaging. These are simply dropped into the spray vat to dissolve in the carrier and form the spray solution. The user is not exposed to the pesticide at any time, increasing the safety of the operation.

Microcapsules
An alternative version of the Bacillus thuringiensis var. kurstaki toxin Cry1A produced in the cells of genetically modified Pseudomonas fluorescens, which die in such a way that they constitute a rigid capsule for the enclosed insecticidal protein. This is claimed to improve protection from UV radiation.

Water quality
The pH of the water used as a carrier for a pesticide is often overlooked when considering the factors that affect the performance of a pesticide. Some pesticides are susceptible to decomposition (or hydrolysis) in acidic or alkaline water. This can have a noticeable effect on the degree of pest control obtained because a certain amount of pesticide will have decomposed before it is actually used. The longer a spray mix is allowed to stand before use, the greater the decomposition of the active constituent. The carrier water pH has the ability to reduce the effectiveness of some pesticides in less time than it takes to spray out the tank mix!

Generally, pesticides are most stable within a pH range of 4.5–7.0, the optimum being pH 5.0–6.0. Some pesticides are not affected by pH and are stable over a pH wide range. Usually, decomposition is more rapid with increasing alkalinity. Insecticides, especially organophosphates, carbamates and synthetic...
pyrethroids, are generally more severely affected by alkaline water than fungicides or herbicides. Some pesticides are incompatible with alkaline materials such as lime, sulphur, calcium chloride and bordeaux mixtures, to name a few. If there is any doubt about the compatibility of certain pesticides, consult the product label.

In some cases, a minor change in the pH can significantly affect the performance of a pesticide. Carbaryl, for example, is a common insecticide used in the nursery industry and it is stable in water at pH 5.0. But in water with pH 7.0, carbaryl decomposes by 50 per cent (also known as a half-life) in 30 days, and at pH 9.0, decomposes 50 per cent in only 24 hours, cutting its effectiveness greatly. To increase pesticide effectiveness, users can follow the following recommendations:

• Do not store and reuse mixed pesticides. Mix and use for each individual job.
• Always read the pesticide label to determine if there are any recommendations for addressing carrier water pH.
• Source information from technical bulletins on products or toll-free numbers that are listed on the product labels.
• Companies that supply buffering agents are also very good sources of information on pesticide stability and products that should be used in specific situations.

Adjuvants

Adjuvants are substances added to a formulation or spray mix for the purpose of improving its performance or stability.

There are many different types of adjuvants, including drift retardants, sequestering agents, synergists, buffers and surfactants. ‘Surfactant’ is a general term used to describe surface active agents, which includes adjuvants such as wetting agents, stickers and anti-foaming agents. Some drift retardants may also be considered surfactants.

Wetting agents

These are sometimes called spreaders or wetters and are sometimes included in a formulation, but in many cases there is a label direction to add a certain quantity of a wetting agent to the spray solution, dependent on the volume being applied. Wetting agents are designed to lower the surface tension of the liquid being applied so that instead of resting as a number of individual droplets on the surfaces targeted, it spreads as an even film with a much larger area of contact. When adding a wetting agent to a pesticide, it is important to always select a non-ionic wetter unless other types of wetters (cationic or anionic) are recommended on the pesticide label. Certain spray oils are registered for use in spray mixes. Care should be taken to follow label directions and to avoid problems with phytotoxicity by not applying pesticides in the heat of the day or in full sun.

Always consult the registered label for advice and recommendations about the use of spray additives.

Synergists

These are chemicals added to a formulation to enhance the performance of the active constituent although alone they have little or no activity. Examples include piperonyl butoxide added to some pyrethroid insecticides to improve knock-down of flying insects and ammonium thiocyanate added to amitrol-based herbicides to improve uptake and weed kill.

Buffers

These are chemicals that can alter and maintain the pH of carrier water at a different level to its normal pH. Some chemicals perform more consistently under slightly acidic conditions and in many places the local water supply is a little alkaline. Acidifying buffers have the ability to lower the pH, which would be an advantage with certain organophosphates, and assist in reducing antagonism when making up mixtures with glyphosate (e.g. Roundup®).

Sequestering agents

These are used in some formulations to overcome the problems caused by hard water containing excessive amounts of calcium and magnesium salts. In a number of phenoxy herbicide formulations, ethylenediaminetetraacetic acid (EDTA) is added as it combines preferentially with the calcium and magnesium present in hard water to form soluble salts. This prevents any 2,4-D acid reactions, which would produce insoluble (solid) salts that would fall out of solution.

Stickers

These help increase the rain-fastness of a spray application, reducing the need for a repeat spray, and are often used as additives to protectant fungicide sprays specifically applied before rainfall events.
Anti-foaming agents

These can save time when recharging spray vats with high pressure water. Excess foam production can occur due to traces of wetting agent left from the previous vat load.

2.3 Transport

Some nursery chemicals are classified as dangerous goods (DG), which means they are subject to the Australian Dangerous Goods Code (available at www.ntc.gov.au/filemedia/Publications/ADG7October2011.pdf – Cited September 2013). With most DG products compliance with the Code does not become a legal obligation until the loads exceed 1 t, but with some products the amount can be as low as 250 kg or L. Compliance involves appropriate documentation, defined responsibilities and vehicle placarding.

If a vehicle is used regularly to transport pesticides it should contain an emergency kit of appropriate PPE, a dry powder fire extinguisher, a shovel, a broom and a bag of neutralising agent, such as hydrated lime.

Loading

• Nursery chemicals should never be transported in the same cabin space as people, pets and food. “Ute it. Don’t boot it.”
• Always check the chemical containers for corrosion and leaks.
• Check containers have complete labels.
• Distribute the load evenly and secure it to prevent movement.
• Do not leave vehicles carrying chemicals unattended.

Unloading

• Check the load is complete.
• Immediately clean up any spillage that may have occurred in-transit.

2.4 Storage of nursery chemicals

Chemicals should normally be obtained shortly before expected use. This will keep the stocks held at a nursery to a minimum and make secure, safe storage a straightforward task.

Storage and handling of containers of pesticide requires particular care and attention. This is an essential part of a safety audit.

**Characteristics of a storage facility**[^1]

The storage area should be:

- located a minimum of 10 m from any dwelling and 15 m from the property boundary
- free of any flood threat or water damage
- clear of vegetation for 3 m around the facility
- constructed of fire-resistant materials
- have a sealed floor that is bunded to contain any spillage
- well ventilated and cool
- kept locked and secure
- placarded to make known its contents.

A storage area should have:

- a reliable water reservoir of clean water for washing and decontamination
- an available emergency shower, preferably fed from a separate storage tank
- the necessary equipment on hand in case of a fire, spill or accidental poisoning
- stock kept off the floor
- the stock grouped by chemical, type or dangerous good (ADG) classifications
- the stock rotated so that unused material is not accumulated
- space available to store empty containers, prior to disposal.


A storage and handling facility that has been well designed has four components:

1. **A storage cabinet or room**

The storage cabinet or room should be located in an area that isolates chemical fumes and dust (i.e. from any personnel), with good ventilation. Many storage lockers are available with good ventilation. Pesticides should be stored at temperatures of 5–35°C.

**Custom-built storage sheds with excellent ventilation, built in showers etc. are available from several manufacturers.**

2. **A mixing area**

The mixing area should contain a work surface and appropriate measuring equipment. A water supply and sink are needed for chemical preparations and clean up. A fume hood may be installed over the mixing table to remove fumes away from workers.
3. A place to store equipment and records
A separate area or room is recommended for storing protective clothing, equipment, records and SDS sheets.

4. An area for loading and rinsing spray equipment
The loading area can be part of the mixing area or it can be separate. It should be large enough to hold the largest sprayer. The purpose of this area is to collect spills while loading and emptying and to provide an area for washing down the sprayers after use. A drench shower and eye wash should be located nearby (Bartok, 1996).

2.5 Personal protective equipment (PPE)
Pesticides are often toxic to mammals and each product has been evaluated in terms of the risk posed to humans. This information is found on the SDS for each product and the recommendations for handling it appear by law on the label of each registered pesticide. Read both of these documents before choosing suitable personal protective equipment for the mixing and application of pesticides. Employers are responsible for the protection of their employees. The employer has a legal duty of care to ensure that workers know how to use personal protective equipment properly. It is important to identify the potential hazards and protect against them.

Modes of pesticide contamination
Pesticides present different risks of poisoning depending on the active chemistry and the carrier. There are several pathways by which pesticides may come in contact with humans—respiratory (by breathing in), dermal (through the skin), ingestion (via the mouth) and insinuative (through puncture or injection).

Each product poses different levels of risk for each pathway and so planning protection will require consideration of the risk posed by every pesticide that will be used. Each product’s SDS contains information on the risk posed by each mode of contamination. Different risks may also be posed by various methods of application and these should be identified by carrying out a risk assessment.

Respiratory exposure and protection
Contaminants can be breathed in through mouth or nose and are absorbed into tissues via the lungs. Respiratory hazards take the form of:

Particulates
- dusts—solid particles moved by air
- mists—liquid droplets suspended in air
- fumes—thermally generated particles.

Gases and vapours
- gases—chemicals that mix with air at room temperature
- vapours—substances that evaporate from liquids and solids at room temperature.

Respiratory protection is provided through properly fitted face masks that remove contaminants by filtering them from the airstream breathed by the user. The Australian/New Zealand Standard AS/NZS 1715–2009 ‘Selection, use and maintenance of respiratory protective devices’ provides comprehensive guidance on how to select the correct type of respiratory protective device (RPD).

Protection from particles
Particulate filters remove material between 0.6 and 2.0 microns in size from the airstream. They filter the air through fibres, which are often electrostatically charged, to attract contaminants as well as mechanically block their movement. Filters clog over time and should be replaced when breathing through them becomes difficult.

Filters are categorised to match specific groups of contaminants.

<table>
<thead>
<tr>
<th>Filter type</th>
<th>Contaminant</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>mechanically generated dusts and mists</td>
</tr>
<tr>
<td>P2</td>
<td>mechanically and thermally generated dusts, mists or fumes</td>
</tr>
<tr>
<td>P3</td>
<td>highly toxic dusts, mists and fumes</td>
</tr>
</tbody>
</table>


Protection from gases and vapours
Gas and vapour filters contain activated charcoal to absorb organic contaminants and remove them from the airstream. The charcoal, usually found in plastic cartridges, is chemically treated to attract and bind particular chemical groups and so must be matched to the contaminants expected in the environment where they are used.
Filter type | Contaminant
--- | ---
A | organic vapours (solvents)
B+E | acid gases
Form | formaldehyde
G | low vapour sprays (most agricultural pesticides)
K | ammonia

Filter classes
Filters of all kinds come in four classes that describe their capacity, i.e. the amount of contaminant they can remove from air.

<table>
<thead>
<tr>
<th>Filter class</th>
<th>Capacity to remove contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Aus</td>
<td>low concentration of contaminant for short durations</td>
</tr>
<tr>
<td>Class 1</td>
<td>higher concentrations or longer duration of use</td>
</tr>
<tr>
<td>Class 2</td>
<td>higher concentrations or longer duration of use</td>
</tr>
<tr>
<td>Class 3</td>
<td>highest concentration of contaminant or longest duration of use</td>
</tr>
</tbody>
</table>

Respirator cartridges
The cartridges fitted to respirators usually consist of both a particulate and a gas/vapour filter. Cartridges containing activated charcoal should be taken off the equipment between uses and stored in a clean, airtight container (such as a re-sealable plastic bag) to avoid deterioration through exposure to water and other vapours. They must be replaced when they are no longer absorbing the gas or vapour, usually apparent when the operator can detect odours while wearing the equipment. Effectiveness of the equipment can be crudely tested by applying a drop of strong smelling perfume or nail polish thinner (acetone) to the air intake of the cartridge before use. If this can be detected by the wearer then the cartridge/s must be replaced.

Powered full helmets
Powered helmets have the advantage of providing filtered air under positive pressure, which increases safety and removes the work of the lungs having to draw in air against filter resistance as in cartridge respirators. A full helmet is necessary for high-risk situations and for spray applicators with beards. All powered air purifying respirators should comply with AS/NZS 1716:2012 and should be fitted with filters appropriate to the particular task.

Dermal exposure and protection
Material can be absorbed through the skin, particularly if there is moisture on the skin, such as sweat. Overalls, gloves, boots, aprons, goggles and face shields are used to mechanically prevent pesticides from reaching the skin. Gloves and boots should be non-absorbent and without lining so that pesticides do not permanently contaminate equipment. Overalls need to be washed between uses and should be removed and replaced if they become visibly wet with spray. Fresh water, soap and showering facilities need to be available where pesticides are mixed and used so that skin can be cleaned immediately in the event of contamination.

Areas of high blood flow such as eyes, ears, face, head and groin have increased absorption rates and particular care should be taken in protecting them. These areas are often scratched or rubbed by operators even when wearing protective gloves, which can lead to contamination of otherwise protected areas.
**Ingestion**

Pesticide material can splash into the mouth, be accidentally eaten, fall onto food or droplets may fall without notice into the mouth and be swallowed. Take care to use a face shield when mixing pesticide concentrates as splashing can occur.

**Insinuative exposure**

Puncture wounds, such as a high pressure spray that breaks the skin or injects material under it, can lead to pesticide exposure. This is more common in glasshouse management than in most other plant industries due to the use of mechanical foggers.

**Hearing protection**

Exposure to the noise of mechanical equipment, especially that of small engines such as those found in foggers, misters and the like can damage hearing. Ensure that operators and other staff have suitable ear protection, such as expanding foam earplugs or earmuffs. Consult resellers/manufacturers to determine what equipment is appropriate for the particular task.

---

**Table 2. Personal protective equipment required for handling pesticides**

<table>
<thead>
<tr>
<th>Protected Area</th>
<th>Equipment Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Overalls</td>
<td>Buttoned at the wrist and neck. These must be clean at the start of each day, splash proof and worn outside the boots.</td>
</tr>
<tr>
<td></td>
<td>Apron</td>
<td>A full-length plastic apron gives added frontal protection when mixing concentrates.</td>
</tr>
<tr>
<td>Eyes</td>
<td>Goggles</td>
<td>To give complete eye protection.</td>
</tr>
<tr>
<td>Face</td>
<td>Face shield</td>
<td>To give protection against face splash.</td>
</tr>
<tr>
<td>Feet</td>
<td>Footwear</td>
<td>Never use absorbent materials such as leather. Use rubber or PVC, preferably with steel toe cap.</td>
</tr>
<tr>
<td>Hands</td>
<td>Gloves</td>
<td>Chemical-resistant, preferably unlined and elbow length (e.g. nitrile PVC gloves).</td>
</tr>
<tr>
<td>Head</td>
<td>Washable cotton hat, overall hood</td>
<td>Head covering to prevent scalp/hair exposure.</td>
</tr>
<tr>
<td>Respiratory system</td>
<td>Respirator</td>
<td>Half or full-face respirator incorporating a cartridge filter system. Refer to the Australian Standard AS/NZS 1716:2012 Respiratory Protective Devices to select the correct respirator and cartridge.¹</td>
</tr>
</tbody>
</table>

¹AS/NZS 1716:2012 Respiratory Protective Devices [Search on Sai Global](Cited September 2013).
Table 3 illustrates the relative risks associated with various types of pesticides, method of application and choice of application equipment. Some operations present a much higher risk to people and property than others.

For each of the various levels of risk a range of personal protective equipment has been suggested. In all instances chemical labels should be read fully and adhered to and the SDS consulted for further information.

### Table 3. Personal protective equipment during spraying operations

<table>
<thead>
<tr>
<th>Risk</th>
<th>Situations</th>
<th>Herbicide</th>
<th>Insecticide/ Fungicide</th>
<th>Method of spray</th>
<th>Choice of equipment</th>
<th>PPE for spraying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low to moderate</td>
<td>Open area</td>
<td>e.g. glyphosate(^1) (e.g. Roundup(^\circ))</td>
<td>e.g. NPVs, Bt (e.g. Gemstar(^\circ), Dipel(^\circ))</td>
<td>High volume (&gt;200 L/ha)</td>
<td>Shielded sprayer, hydraulic boom, knapsack.</td>
<td>Overalls, boots, goggles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate to high</td>
<td>Shadehouse</td>
<td>e.g. fluazifop-p-butyl(^2) (e.g. Fusillade(^\circ))</td>
<td>e.g. carbaryl(^1), mancozeb(^1) (e.g. Dithane/M45(^\circ))</td>
<td>Low volume (10–200 L/ha)</td>
<td>Hydraulic boom, spinning disc (herbi), airshear</td>
<td>Overalls, gloves, boots, washable hat, appropriate respirator (where indicated on label), face shield, goggles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High to very high</td>
<td>Enclosed area (glasshouse)</td>
<td>e.g. paraquat(^1) (e.g. Gramaxone(^\circ))</td>
<td>e.g. methidathion(^1) (e.g. Supracide 400(^\circ))</td>
<td>Ultra low volume (&lt;10 L/ha)</td>
<td>Electrostatics, spinning disc (ulva), foggers (ULV/CDA)</td>
<td>Overalls, gloves, boots, full-face respirator (or goggles and ½ face respirator), face shield, washable hat, goggles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing</td>
<td>Most pesticides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Overalls, gloves, boots, full-face respirator (or goggles and ½ face respirator), face shield, washable hat and apron</td>
</tr>
</tbody>
</table>

\(^1\) Caution (low potential for harm, domestic poisons)  
\(^2\) Poison (moderate potential for harm, industrial and agricultural poisons)  
\(^3\) Dangerous poisons (high potential for harm, special poisons)
Maintenance of personal protective equipment

- All PPE should be cleaned as soon as possible after each use. It must not be contaminated with residues from a previous occasion.
- Soaking overalls in a slightly alkaline bleach solution (such as ammonium or sodium hydroxide) will prevent residues becoming ‘fixed’ in the fabric and break down any organophosphate or carbamate pesticide residues that may be present.
- A similar solution may be used to wipe over other items of PPE prior to storage.
- It is wise to check all items prior to storage for signs of wear and tear so that replacements can be obtained before the next occasion the equipment is needed.
- Respirator cartridges should always be removed and stored in a clean air-tight container (such as a resealable zip-lock plastic bag) to prevent a reduction in useful life (see page 23).
- The usage period of respirator cartridges containing activated charcoal should be recorded and they should be tested for efficiency regularly (see page 23).
- Care should be taken to service the inhalation and exhalation valves in the body of cartridge respirators.

The spray operator must wear protective clothing as recommended on the label when mixing and applying pesticides.

Protective clothing and equipment should be checked before use, cleaned and checked after every day’s use and then stored in a clean dry area away from pesticides.

Mixing the concentrate when preparing to spray can be the most hazardous time for the operator.

2.6 Disposal

It is the responsibility of the user to see that wastes such as unused chemicals and empty containers are disposed of properly. Empty containers can be a hazard to curious children and animals. Improperly disposed of chemicals can result in water contamination and crop damage. The current AgSafe® Accreditation Training Manual (2002) has further information on this topic.

There are services available that can be used to dispose of chemical waste and containers. Such services include drumMUSTER and ChemClear®.

The following steps are guidelines for disposing waste properly:
- Purchase only the required amount of pesticide needed for one season to avoid disposal problems associated with excess product.
- Always read the label for disposal instructions.
- Wear the appropriate protective clothing during the disposal of any unwanted pesticide or pesticide mixture.
- Treat contaminated clothing and protective equipment, contaminated soil or materials used to clean up spills in the same manner as nursery chemical waste. The current AgSafe® Accreditation Training Manual (2002) has further information on this topic.
- Use accredited disposal schemes, such as drumMUSTER and ChemClear, where available®.

The label must remain on the container at all times.
drumMUSTER

DrumMuster is the national program for the collection and recycling of empty, cleaned, non-returnable crop production and on-farm animal health pesticide containers. Containers will be inspected for visible signs of pesticide residue or any liquid before being accepted for re-use or recycling. For the DrumMuster website refer to the contact details on page 84.

Disposing of unused mixed product

Small amounts of excess pesticide mixture are frequently left at the end of an application and are also created when rinsing spray tanks or empty pesticide containers. This material must be disposed of properly. Check the pesticide SDS for specific risks of contamination.

This material must never be allowed to enter streams or drainage from the property.

Excess spray can be disposed of by spraying over the crop, although care should be taken that authorised rates of application are not exceeded by the addition of this application to the treatment previously applied. Alternatively, a mulched area might be used, with the same provision concerning registered rates of application per area.

Areas where mixing and cleaning of equipment are performed create risks of pesticide spillage. They should be bunded to prevent run-off or drainage to watercourses and suitable materials kept nearby for the neutralisation of spilled material. Wash water collected from this area must be retained to allow pesticide breakdown.


Cleaning spray equipment

Rinsing

Spraying equipment should be cleaned in the same manner as pesticide containers to remove spray residues that may clog equipment or present a safety hazard. This should be performed directly after use to prevent drying or caking, which may be difficult to remove later. The inside of the spray tank must be rinsed out and the rinsate run out through the nozzles or other applicator until the tank is empty. This should be repeated at least twice and the outside of the equipment inspected for visible residues.

Neutralising

Plastic and fibreglass spray tanks and the plastic spray lines absorb trace quantities of pesticides during use. This can later create hazardous vapours or contaminate spray mixes of other materials. This can create risks for operators and target plants, depending on the pesticides used. Ideally, use separate spray tanks for different groups of pesticides used, i.e. herbicides, insecticides and fungicides, or members within these categories used for different management activities. Consulting the records of pesticides previously applied with equipment can avoid expensive mistakes, damaging sensitive crops or endangering staff.

While separate equipment may be an option for large plant nurseries, most operators will want to neutralise the residues in equipment from time to time so that they can safely use it for a variety of purposes.
Table 4. Recommendations for use of cleaning agents

<table>
<thead>
<tr>
<th>Chemical used</th>
<th>Cleaning agent per 100 L water</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>All herbicides</td>
<td>Commercial cleaning agent</td>
<td>Follow directions of cleaning agent label.</td>
</tr>
<tr>
<td>Phenoxy herbicides (2,4-D, Dicamba, MCPA etc)—salt and amine formulations</td>
<td>1–2 L household ammonia per 100 L water or</td>
<td>Thoroughly agitate, flush small amount through system and let remainder stand in sprayer overnight. Flush and rinse with clean water several times before use.</td>
</tr>
<tr>
<td></td>
<td>500 g washing soda or</td>
<td>Same as above but let stand for at least 2 hours.</td>
</tr>
<tr>
<td></td>
<td>1 kg trisodium phosphate per 100 L water or</td>
<td>Same as above but let stand for at least 2 hours.</td>
</tr>
<tr>
<td></td>
<td>250 g fine activated charcoal and half a cup of detergent (liquid or powder) per 100 L water</td>
<td>Make a sudsy solution. Agitate, operate sprayer for 2 minutes, let remainder stand for at least 10 minutes, then flush through sprayer. Rinse.</td>
</tr>
<tr>
<td>Phenoxy herbicides—ester formulations</td>
<td>500 g washing soda + 4 L kerosene + 125 g powder detergent</td>
<td>Rinse inside of tank and flush small amount through system. Let stand for at least 2 hours. Flush and rinse.</td>
</tr>
<tr>
<td>Sulfonylurea herbicides</td>
<td>500 ml sodium hypochlorite (chlorine) bleach (6% solution)</td>
<td>Flush through the boom for at least 10 minutes including spraying out the jets. Make sure all spray lines, filters etc are well cleaned. Rinse out. Repeat the operation for at least another 10 minutes. Allow the sprayer to stand for at least 12 hours.</td>
</tr>
<tr>
<td>Other herbicides</td>
<td>125 g powder or liquid detergent to make a sudsy solution</td>
<td>Rinse with clean water afterwards.</td>
</tr>
<tr>
<td>Insecticides and fungicides</td>
<td>125 g powder or liquid detergent to make a sudsy solution</td>
<td>Rinse with clean water afterwards. Organophosphate and carbamate insecticide may be detoxified by adding household ammonia to the cleaning solution at 1 L per 100 L water.</td>
</tr>
</tbody>
</table>


Rinsing containers

Rinsing and cleaning containers are the first steps in proper disposal. State laws require users to follow label instructions that specify that containers must be rinsed. Local shire and municipal councils will only accept properly rinsed and cleaned containers at their approved refuse landfills, after inspection of the containers. Under current regulations in most states, containers that have not been properly rinsed can be classified as hazardous wastes.

Containers should be rinsed directly after emptying their contents as residues are more difficult to remove when dry. Proper rinsing of nearly all types of pesticide containers will remove more than 99% of any pesticide residue remaining in the container. Rinsing into the spray tank also conserves valuable pesticide.

Two commonly used procedures are effective for proper rinsing of pesticide containers: 1. pressure rinsing and 2. triple-rinsing. Clean water must always be used to rinse containers.
Pressure rinsing

Some spray equipment manufacturers supply a special rinsing attachment that enables drums and bags to be rinsed using a pressure nozzle. This method is generally faster and easier to carry out than triple-rinsing (AgSafe® Accreditation Training Manual, 2002). There are two basic forms: 1. the ‘piercing nozzle’ and 2. ‘sucker-flusher’ probes. The piercing nozzle makes its own hole and is inserted into the bottom or side of the container. In this case the rinsate flows out through the regular opening. Sucker-flusher probes enter through the normal aperture and suck fluid from the bottom of the container while spraying pressurised water from nozzles on the side of the probe back from the head.

1. Remove the cap from the container. Empty contents into the tank and allow to drain for an extra 30 seconds after the flow reduces to drops.
2. For piercing nozzles, insert the pressure nozzle by puncturing through the lower side of the container. Do not, however, puncture plastic containers (such as 20 L drums) if they are part of a manufacturer’s re-use program; these should be triple-rinsed. For sucker-flusher probes, insert through the regular opening and do not invert the container (i.e. ignore step 3).
3. Hold the container upside down over the sprayer tank so the rinsate will run into the sprayer tank.
4. Turn the water on and rinse for the length of time recommended by the manufacturer (normally at least 30 seconds) or until the rinsate coming from the container is clear. Move the nozzle or probe about so that the stream of water reaches all parts of the container to rinse all inside surfaces.
5. Rinse the container cap when there is a clear stream of water coming out of the container, or alternatively, rinse separately in a bucket of water and pour this into the spray tank.
6. Check the container thread and the outside surfaces of the container and, if contaminated, rinse with a hose into the spray tank.
7. Look inside the container to ensure it is thoroughly clean.
8. Let the container dry completely (this may take several days), then replace the cap.
9. Store containers where they can remain clean and dry until they can be taken to a collection or disposal site.

Triple-rinsing

Triple-rinsing is a three-stage manual rinsing process, involving the following steps:
1. Remove the cap from the container.
2. Empty the contents into the spray tank and allow the container to drain for an extra 30 seconds after the flow reduces to drops.
3. Fill the container with water to between 20% and 25% of its capacity.
4. Replace the cap securely.
5. Shake, rotate, roll or invert the container vigorously for at least 30 seconds, so that the rinse reaches all inside surfaces. For 200 L drums, rolling between two people is advised.
6. Remove the cap. Add the rinsate from the container into the sprayer tank. Let it drain for an extra 30 seconds after the flow reduces to drops.
7. Repeat steps 3–6, two more times.
8. Check the container thread and the outside surfaces of the container and, if contaminated, rinse with a hose into the spray tank.
9. Look inside the container to ensure it is thoroughly clean.
10. Wash the cap.
11. Let the container dry completely (this may take several days), then replace the cap.
12. Store containers where they can remain clean and dry until they can be taken to a collection or disposal site.

2.7 Environmental protection

Any pesticide material that does not reach or remain on the target may pollute the atmosphere, water and soil. These are important natural resources and operators have a legal responsibility to avoid contaminating them. Potential sources of pesticide pollution include:
• drift of droplets in air away from the target area
• pesticide transported by water from the target area:
  » leaf run-off due to excess spray volume or overly large droplets
  » irrigation or rainfall on recently sprayed areas
• droplets falling on soil where there is incomplete canopy cover by target foliage
• rinsate from equipment washing and spray mixing
• leaching from pesticide treated potting mixture.

*Refer to the drumMuster fact sheet ‘Effective rinsing of farm chemical containers’ (Cited September 2012)
**Atmospheric contamination**

Pesticide droplets that are carried in the air away from the target can cause significant damage to other, non-target plants and unprotected people, soil and water. This is commonly referred to as ‘spray drift’ and is the main theme of chapter 3 of this manual.

**Soil contamination**

Pesticides contacting the soil may be adsorbed on soil minerals and organic matter or remain in a soluble form that can be moved by water. Contaminants may leach into the water directly or may be carried on soil particles, particularly during storms and irrigation. Contaminated soil also creates hazards through direct skin exposure to the soil, inhalation of pesticide in dust or vapours moving into the air. Persistent pesticide contamination in soil can move into the surrounding environment over time, thus creating an ongoing source of pollution.

**Water contamination**

Water rapidly spreads pollution through the environment. Pesticides can remain active even at very low concentrations, creating adverse impacts on environmental and community health. Many pesticides are toxic to mammals and pose a direct health hazard. Water in populated areas is tested regularly for contamination and the likelihood of poor management being identified and prosecuted is high. Further, many birds and aquatic life forms (e.g. fish and crustaceans) are extraordinarily sensitive to insecticides and herbicides. Pesticide pollution exposes operators to prosecution under state laws governing environmental protection.

Pesticide residues can also be carried by water to the watertable. These contaminants are no longer exposed to the normal biological and physical factors such as micro-organisms, heat, light and air that degrade pesticides. Thus, groundwater contamination can be very persistent.

**Pesticide degradation**

While pesticides may have a shelf-life of two or more years in storage as concentrated form, dilute sprays in the natural environment are expected to degrade more swiftly. This is a major consideration in the creation of product advisory information during registration.

Factors that increase the breakdown of pesticide molecules include:
- exposure to direct sunlight (UV)
- soil and plant micro-organisms
- high temperature
- filtering, through sand, vegetation or organic matter
- aeration (if in water)
- plant metabolism.

Table 5 contains data on the breakdown and persistence of some pesticides in the environment. While this illustrates the general differences between types of chemical, actual performance will depend strongly on soil type, water quality and other environmental factors.

**Managing pesticide contaminants in soil and water**

Assess the pathway of drainage water from areas of pesticide application. What sensitive areas are in the downstream environment? Consult each SDS to determine the specific risks each pesticide poses, including all soil and potting-mix treatments. What flows of water are expected under normal operation and during floods?

Due to their intense management of production areas, nurseries are more able to manage water than most other plant industries. When designing drainage for a production area consider ways to maximise the factors that increase pesticide degradation. For example, if soil is well drained, seal the floor of the production area with a plastic sheet under the gravel to prevent water travelling down into the soil profile. Expose water leaving the target area to unpasteurised soil and sunlight and ideally filter it slowly through a sand bed. If water can be collected, do so in shallow, aerated ponds, with reeds or other water plants. If water is otherwise of suitable quality, it may be economical to treat it and recycle it for re-use as irrigation water, which further decreases risks posed to the surrounding community.

The quality of water leaving commercial properties is likely to come under increasing scrutiny in the near future, and careful planning of growing areas now may help to avoid costly liability later.

To reduce the risk of polluting soil and water with pesticide:
- Plan to leave most spray on the target:
  » avoid run-off, don’t over-spray or use the largest droplet sizes, which can roll off leaves
  » avoid drift from the target area.
- Ensure the correct rate per area or concentration is being applied at the correct frequency and use properly calibrated equipment.
<table>
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<tr>
<th>Trade name</th>
<th>Common name</th>
<th>Soil sorption index ($K_{oc}$)</th>
<th>Water solubility (ppm)</th>
<th>Soil half-life (days)</th>
<th>Surface runoff</th>
<th>Leaching</th>
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<td>3</td>
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<td>Maneb</td>
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<td>medium</td>
</tr>
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<td>110</td>
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<td>medium</td>
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<td>Vitavax</td>
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<td>medium</td>
<td>small</td>
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</tbody>
</table>

Source: Colorado State University, Best management practices for agricultural pesticide use
• If the soil is naturally well drained, use an impermeable layer under the production area to avoid groundwater contamination and consider recycling run-off to filters, ponds etc.
• Prevent erosion of soil that may receive spray.
• Pesticide-treated potting soil is contaminated. Do not allow water to run through it and then to waste. Reuse or allow it to break down where it cannot drain into an uncontrolled waterway. Drainage systems should be designed to collect and hold run-off water on site.

2.8 The law and nursery chemicals
Laws exist at both the federal and state level to regulate the use of pesticides. These are aimed at ensuring the safety of operators, the environment and the community. In general, responsibility for pesticides prior to the point of sale is regulated by federal legislation and the responsibility for transport, storage and application after sale is regulated by separate legislation in each state and territory.

Disclaimer
This manual attempts only to outline the areas of legislation concerned with pesticide management and does not seek to provide information on the specific laws or their application in the states and territories of Australia.

Laws and practices vary between states, as do the application of some federal standards. They are subject to constant revision and up-to-date information should be sought for each inquiry. To ensure you are aware of the Acts and Regulations that may affect the way you operate, contact your state Nursery Industry Development Officer for more details.

Other reliable sources of information include:
• commonwealth, state and territory departments of agriculture, primary industries, lands or environment
• certified agricultural safety trainers e.g. ChemCert.

See contact details on pages 84–85 for ways to obtain further information on agricultural pesticide use legislation for each state in Australia.

Duty of care
People handling pesticides, and their employers, have a duty of care to comply with all safety requirements of storage, handling and use. Duty of care legislation in contract or common law covers acts or omissions that cause harm. It is the responsibility of workplace managers to ensure safe practice and they are directly responsible for the compliance of employees in the workplace. They are also responsible for the safety of all equipment used, employee protection from exposure to risk and protection of the environment.

Federal law
Australian Pesticides and Veterinary Medicines Authority
For a pesticide to be sold or legally used in a nursery in Australia it must be registered by APVMA. APVMA examines each product in the areas of:
• human toxicology
• environmental impact
• occupational health
• efficacy.

APVMA invites public comment before granting clearance or otherwise. It may also administer ‘minor use’, ‘permit’ and ‘off-label’ schemes, usually in conjunction with relevant state departments, to supervise small market uses not large enough to support the cost of generating normal data submission packages and label extensions.

National Standards (AS)
Australian Standards exist for storing and handling pesticides. Each state has legislation that covers these areas and recognition and application of the national standards varies widely between states. The current relevant Australian Standards are:
• AS 1940 (2004) The storage and handling of flammable and combustible liquids
• AS 2507 (1998) The storage and handling of agricultural and veterinary chemicals
• AS/NZS 4452 (1997) The storage and handling of toxic substances
• AS/NZS 3833 (2007) The storage and handling of mixed classes of dangerous goods, in packages and intermediate bulk containers
State and territory law

Once clearance has been given for sales to proceed, a pesticide is subject to the legislation of each state. This involves a number of different legal Acts with their accompanying Regulations. In some cases the formal legislation is supported by ‘codes of practice’ or ‘compliance guidelines’, which are documents designed to assist in understanding what the law requires.

It is important that nursery operators are aware of the regulations that may affect or limit the types of operations they may wish to carry out in each state or territory. The current AgSafe® Accreditation Training Manual (2002) provides an excellent summary of this area on a state-by-state basis.

Examples of SOME areas where legislation exists relating to the nursery industry include:

- the use of particular pesticides and how they may be applied
- the operation of particular pieces of equipment, and where they may be operated
- workplace health and safety Regulations and who may apply pesticides
- health Acts and Regulations that determine how and where pesticides may be stored, used and disposed of
- environmental protection Acts that encompass water, air and noise management
- noise pollution Regulations for powered equipment
- numerous others, depending on the location of the nursery.

In some states within specific regions special, more restrictive regulations apply to the use of agricultural chemicals. For example in Victoria, Agricultural Chemical Control Areas (ACCAs) exist where the use of some chemicals is prohibited unless authorisation and a permit has been received that includes notifying the local authority of the time, date and exact location of the proposed chemical application.

Occupational health and safety legislation

There is also considerable legislation that regulates pesticide use, even though not directly addressing it. Of particular interest for managers and operators are laws concerning occupational health and safety. These laws generally cover:

- identification of hazards
- risk management
- risk reporting
- activities in the workplace
- emergency response (safety, first aid, spill management)
- facilities
- personal protective equipment
- hazardous substances
- training monitoring and records.

Workplace managers are directly responsible for employee compliance to these laws.

A process of legislative harmonisation is currently underway nationally to bring states under the standardised Work Health and Safety Act 2011. The main objective of this process is to provide for a balanced and nationally-consistent framework to secure the health and safety of workers and workplaces. The national legislation has already been adopted by some states and territories while others are operating under temporary transitional arrangements and others are unwilling to sign up to the proposed Act. It is recommended that advice be sought from the relevant state or territory government to determine the progress of the harmonisation process at the time of reading. Links to all agencies are available from http://www.safeworkaustralia.gov.au or by calling 1300 551 832.

Table 6. Occupational health and safety legislation in Australian states

<table>
<thead>
<tr>
<th>State/territory</th>
<th>Acts and Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Capital Territory</td>
<td>Work Health and Safety Act 2011</td>
</tr>
<tr>
<td>New South Wales</td>
<td>Work Health and Safety Act 2011</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>Work Health and Safety (National Uniform Legislation) Act 2011</td>
</tr>
<tr>
<td>Queensland</td>
<td>Work Health and Safety Act 2011</td>
</tr>
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<td>South Australia</td>
<td>Work Health and Safety Act 2012</td>
</tr>
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<td>Tasmania</td>
<td>Work Health and Safety Act 2012</td>
</tr>
<tr>
<td>Victoria</td>
<td>Occupational Health and Safety Act 2004</td>
</tr>
<tr>
<td>Western Australia</td>
<td>Occupational Safety and Health Act 1984</td>
</tr>
</tbody>
</table>
Spray drift is a major consideration in relation to the safe use of pesticides.

Spray drift is the movement of a pesticide (as droplets in the air) outside the intended target area. This off-target movement of pesticide has the potential for injury or damage to humans, plants, animals, the environment or property.

Spray drift does not include off-target movement of a chemical due to post-spray volatilisation or movement in water, soil or organisms, although this chemical movement can also be very damaging (see sections 2.5 to 2.7).

It is recognised that nearly all spray application of pesticide results in some spray drift. However, if uncontrolled and excessive, spray drift can cause:

- damage to crops in neighbouring areas
- contamination of neighbouring crops resulting in illegal residues on produce
- loss of expensive chemical and reduced efficacy on target pests
- death of beneficial organisms such as bees, and predators and parasites of pest organisms
- environmental contamination
- adverse publicity and community concern.

Spray drift is usually the result of:

- spraying in unsuitable weather conditions
- using spray equipment inappropriately (i.e. use inconsistent with manufacturer's instructions or training guidelines)
- using an unsuitable (e.g. unregistered or unapproved) pesticide formulation for a particular use or in a particular area
- failing to identify and allowing spray to drift onto susceptible non target areas
- using a droplet size that is too small.

In plant nursery operations drift can occur internally to other parts of the nursery (e.g. neighbouring plants or areas where other staff are working) or externally to the nursery (e.g. neighbouring houses or fields). It is important to consider the potential for both internal and external drift before undertaking the application of pesticides.

3.1 Managing spray drift

There are four main methods that can be used to reduce spray drift in the nursery. These are:

1. Control droplet size when applying sprays or use solid formulations such as granules.
2. Use appropriate application techniques.
3. Select the correct meteorological conditions.
4. Use buffer zones (including vegetative and artificial structures).

Droplet size

Droplet size is probably the single most important factor in managing potential pesticide spray drift. Because large droplets fall towards the ground significantly faster than small droplets, the airborne transport of droplets is significantly reduced if small droplet production is kept low.

However, all droplets used for spraying pesticides are small! Droplets are measured in micrometres (µm). It is easy to refer to droplets of 10, 100 or 500 µm, forgetting that 10 µm and even 100 µm droplets may not be visible to the naked eye.

As an example, the full stop at the end of this sentence is approximately 300 µm in diameter. A micrometre is 1/1000 of a millimetre (mm) and thus a 500 µm droplet is half a millimetre in diameter. A 500 µm diameter droplet is considered a large droplet in spray application technology.
Droplet behaviour under optimum spraying conditions

In general terms we can say that droplets in the following size ranges will behave as described below:

<table>
<thead>
<tr>
<th>Approximate droplet size</th>
<th>Expected behaviour under suitable spraying conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 50 µm</td>
<td>If water based, will evaporate quickly and will typically be lost before reaching the target.</td>
</tr>
<tr>
<td>Droplets 50–150 µm</td>
<td>Will move with air movement (wind), and may move off-target. However, if managed well under good spraying conditions, they can improve target penetration and coverage.</td>
</tr>
<tr>
<td>Droplets &lt; 200 µm</td>
<td>Considered 'driftable' because they may reduce in size due to evaporation (if water based), and hence move with the wind.</td>
</tr>
<tr>
<td>Droplets &gt; 350 µm</td>
<td>May bounce or run off without the addition of adjuvants, hence may not be useful for spraying foliage.</td>
</tr>
</tbody>
</table>

Droplets between 100 and 350 microns are considered the MOST USEABLE fraction of the spray cloud when spraying foliage (e.g. useful for many insecticide sprays).

Estimators of droplet size in the droplet cloud

Unfortunately, no practical spray nozzles are currently available to produce droplets that are all the same size. All commercial nozzles generate a range of droplet sizes. It is therefore difficult to exactly describe the output from a spray nozzle in terms of droplet size produced. Some pesticide labels describe the droplet size to be used by an applicator in terms of the volume median diameter (VMD).

The VMD divides the droplet spectrum into two equal parts. One half of the total spray volume is made up of droplets larger than the VMD and the other half made up of droplets smaller than the VMD. A diagrammatic representation of VMD is shown in figure 5. If droplets from a spray nozzle could be lined up in order of size, the VMD indicates the droplet size that would divide the sample in half by volume.

Two different nozzles may produce the same VMD but may actually produce quite a different droplet cloud. One nozzle may produce droplets that all fall in a very narrow band around the VMD while the other nozzle may produce a broad spectrum of droplet sizes.

Most hydraulic nozzle manufacturers’ catalogues now indicate droplet size produced using the spray quality categories of very fine (the smallest), fine, medium, coarse and very coarse (the largest). Refer to table 7 for the designation of droplet size ranges in microns.

An example from the Spraying Systems Co. catalogue is shown in figure 6. This scheme of describing droplet size was originally devised by the British Crop Protection Council (BCPC) during the mid 1980s as a means of standardising the relationship between a variety of measurement systems and describing the entire droplet spectrum generated by a spray nozzle. Currently, air induction nozzles are not included in the classification scheme. To reduce drift, select nozzles and pressure settings that produce a coarse or very coarse spray.

Spraying Systems Co. catalogue

Figure 5. Illustration of the volume median diameter (VMD)
3.2 Understanding spray quality classifications

A number of nozzle manufacturers provide information on the spray quality from their hydraulic nozzles (for ground application) at various pressures according to the British Crop Protection Council (BCPC) and American Society of Agricultural & Biological Engineers (ASABE) standards.

Table 7. ASABE droplet categories, average sizing and potential uses (ASAE S572.1)

<table>
<thead>
<tr>
<th>ASAE category</th>
<th>Colour code</th>
<th>VMD of droplet cloud</th>
<th>Potential uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely fine (XF)</td>
<td>purple</td>
<td>&lt; 60 µm (microns)</td>
<td>insecticide</td>
</tr>
<tr>
<td>Very fine (VF)</td>
<td>red</td>
<td>61–144 µm</td>
<td>insecticide</td>
</tr>
<tr>
<td>Fine (F)</td>
<td>orange</td>
<td>145–235 µm</td>
<td>fungicide</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>yellow</td>
<td>236–340 µm</td>
<td>herbicide/insecticide</td>
</tr>
<tr>
<td>Coarse (C)</td>
<td>blue</td>
<td>341–403 µm</td>
<td>herbicide</td>
</tr>
<tr>
<td>Very coarse (VC)</td>
<td>green</td>
<td>404–502 µm</td>
<td>herbicide</td>
</tr>
<tr>
<td>Extremely coarse (XC)</td>
<td>white</td>
<td>503–665 µm</td>
<td>herbicide</td>
</tr>
<tr>
<td>Ultra coarse (UC)</td>
<td>black</td>
<td>&gt; 500 µm</td>
<td>herbicide</td>
</tr>
</tbody>
</table>

Examples of spray quality charts for various nozzle types

Figure 6. BCPC classification scheme used to define spray quality by spraying systems (F=fine, M=medium, C=coarse, VC=very coarse)
An example of the use of these classifications is provided below, which is an excerpt from the Spraying Systems Teejet® catalogue.

What are the BCPC and ASAE S572.1 classifications?

The BCPC and ASAE S572.1 classifications describe spray quality (the range of droplet sizes produced by a nozzle). This spray quality is determined by comparing a nozzle’s output of different sized droplets (droplet spectrum) at a given pressure against the outputs of a set of standard reference nozzles. This is done using a laser-based instrument and, due to the comparative nature of the standard, nozzles will achieve the same classification regardless of testing technique.

There are three key measurements used in determining the spray quality classification. These describe the proportion of volume through the nozzle resulting in different size categories.

<table>
<thead>
<tr>
<th>Key measurements</th>
<th>Proportion of volume in different size categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D[v0.1]$</td>
<td>10% of the spray volume produced by the nozzle results in droplets smaller than this size (diameter in microns).</td>
</tr>
<tr>
<td>$D[v0.5]$</td>
<td>Also known as the volume mean diameter (VMD). 50% of the spray volume produced by the nozzle is in droplets smaller than this size (diameter in microns). 50% of the spray volume is in droplets larger than this size.</td>
</tr>
<tr>
<td>$D[v0.9]$</td>
<td>90% of the spray volume produced by the nozzle is in droplets smaller than this size (by diameter in microns).</td>
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</tr>
<tr>
<td>$D[v0.9]$</td>
<td>90% of the spray volume produced by the nozzle is in droplets smaller than this size (by diameter in microns).</td>
</tr>
</tbody>
</table>
These three measurements are plotted on a graph to produce boundaries for each spray quality classification. A reference curve from a Malvern laser instrument, as shown in figure 8, is used for this purpose.

Figure 8. Example of BCPC reference curves used to determine spray quality

Using reference curves to understand nozzle outputs

By using the reference curves in conjunction with the spray quality classifications, nozzle outputs can be better understood. For example, a nozzle that has been assigned a FINE spray quality will produce droplet sizes within a particular range.

Figure 9 shows that a fine nozzle will have a 
D[v,0.1] of 60–100 µm. This means that 10% of the spray volume is in smaller droplets than these sizes. A fine nozzle will also have a 
D[v,0.5] or VMD of 131–239 µm.

Where a particular nozzle can produce a FINE spray quality at a range of spray pressures, the droplet sizes produced will be largest when operated at the lowest pressure required to stay within the FINE classification (towards 239 µm).

If the nozzle is operated at the highest possible pressure to stay within a FINE spray quality the droplet sizes produced will be smaller. It is possible that the VMD could be as small as 131 µm.

By understanding how droplets of various sizes behave in differing conditions, the reference charts can be used to estimate the spread of droplet sizes produced when operating nozzles to deliver spray. Pesticide applications can be better planned using this information.

Figure 9. Using the reference curves and spray quality charts
Using BCPC spray quality classifications to select nozzles

When selecting a nozzle for a particular purpose, an understanding of what the classifications mean in terms of the types of droplets each classification includes is required. The behaviour of various droplet sizes can then be used to select the appropriate nozzle for particular situations. For example, in a situation where drift would be of particular concern, it is important that after determining the desired droplet size for the target (which should be close to the VMD) a nozzle is selected with the largest possible size of ‘fine’ droplets $D_{v,0.1}$.

Droplet sizes for different targets

Regardless of the target, the objective should be to obtain the best coverage possible while minimising the off target losses, such as drift or run-off, as much as practicably possible. The understanding of the droplet sizes required for different targets is gradually improving. Recommendations for the application of different pesticides onto different targets are continually being developed so it is important to keep up-to-date with developments.

Label instructions need to be followed for the correct application of particular product types. Where this information is not provided the general principles provided in table 8 can be applied.

Table 8. General guide to application of different product type

<table>
<thead>
<tr>
<th>Product types</th>
<th>Spray classification</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecticides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact</td>
<td>Fine–Medium</td>
<td>If using the finer end of the droplet spectrum.</td>
</tr>
<tr>
<td>Systemic</td>
<td>Fine–Medium</td>
<td>If using medium, stay at the finer end.</td>
</tr>
<tr>
<td>Fungicides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protectant</td>
<td>Very fine–Fine</td>
<td>Be aware of droplet spectrum and evaporation.</td>
</tr>
<tr>
<td>Curative/eradicant</td>
<td>Fine–Medium</td>
<td>If using medium, stay at the finer end.</td>
</tr>
<tr>
<td>Herbicides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil applied</td>
<td>Coarse</td>
<td>Use appropriate water volumes to ensure coverage.</td>
</tr>
<tr>
<td>Contact</td>
<td>Medium</td>
<td>Medium preferred where conditions allow.</td>
</tr>
<tr>
<td>Systemic</td>
<td>Medium–Coarse</td>
<td>Use at the coarse end and monitor conditions.</td>
</tr>
</tbody>
</table>

Nozzle types

Nozzle selection is an important factor when considering spray drift. It is well known that spray drift can be minimised—and spray efficiency maximised—by selecting an appropriate nozzle for a spray job. Most pesticide labels do not provide recommendations for a specific nozzle for a particular job. However the ASAE categories (extremely fine, very fine, fine, medium, coarse, very coarse, extremely coarse and ultra coarse) enable the spray performance of most common hydraulic systems to be characterised. The system allows operators more choice in selecting a nozzle type, size and pressure for a particular task, provided the selected combination produces the droplet size that falls within the specified category. Notice that in the example shown in figure 6 the droplet size generated by a Spraying Systems Turbo TeeJet* increases as orifice size is increased and spray pressure is reduced.

Spray pressure

Spray pressure should be as low as possible, consistent with nozzle specifications and coverage requirements. Check the manufacturer’s nozzle catalogues for recommended pressure of operation.

When the pressure at the nozzle is increased, most hydraulic nozzles generate a finer droplet spectrum. To reduce drift potential, use low pressures.

Many nozzle manufacturers now provide low pressure nozzles that can be operated as low as 100 kPa (where 100 kPa = 1 bar = 15 psi). This will be marked on the nozzle with the other specifications as ‘LP’.
It is important to note that:
- spray volume should be controlled by changing nozzles not by changing pressure, i.e. selecting nozzles with a greater throughput to increase volume
- all sprayers should be fitted with an accurate, easy to read pressure gauge.

**Nozzle spray angle**

A flat fan nozzle that has a wider spray angle will normally produce a thinner sheet of spray solution, which results in smaller droplets than will be produced by a narrower angle nozzle operating at the same pressure. For example a 110° flat fan can normally be expected to generate a finer droplet spectrum than an 80° flat fan operated at the same pressure with the same orifice size (and flow rate). In terms of drift control, the benefits of a lower nozzle height provided by a wide-angle nozzle, can outweigh the disadvantages associated with smaller droplet spectrum produced due to the wider angle nozzle.

**Spray volume**

A larger nozzle orifice increases the droplet size when operated at the same pressure as a smaller nozzle orifice. It will also increase the rate of flow and thus the amount of spray used per unit of time. This results in the use of more carrier fluid per area at the same speed of application, and the concentration of pesticide should be lowered accordingly.

**Application techniques**

**Release height**

Release height of the spray is an important factor that influences the potential for spray drift. The higher droplets are released, the greater the potential for drift. Release height of sprays should be as low as possible, consistent with nozzle specifications and target coverage requirements (see diagram below).

When boom sprayers are fitted with flat fan nozzles, boom height should not exceed the optimum height as specified by the nozzle manufacturer. The height (h) required to sufficiently overlap spray patterns varies depending on the angle of spray emission (e.g. 80°, 110°) from the nozzles. With most 110° flat fan nozzles, a minimum height of 35 cm, and a maximum of 50 cm, above the target is usually recommended.

**Boom stability**

On boom sprayers, adequate boom stabilisation is essential to prevent sway and dipping, which alter the height and evenness of spray. This is especially important for operation on uneven ground. Boom height may be lowered to produce less spray drift, although modification to nozzle number, type and orientation is usually required to maintain an even spray pattern across the boom. The use of wide-angle flat fan nozzles (e.g. 110°) usually permits lower boom heights to be used effectively.

**3.3 Meteorology**

The weather plays an important role in controlling the fate of pesticides applied as sprays. It is essential that operators engaged in spraying are aware of the immediate environmental parameters. Low cost, hand-held anemometers and psychrometers are available to monitor wind velocity and humidity respectively. The purchase of meteorological station data loggers is recommended for larger enterprises that regularly apply pesticides.

The spray operator must observe wind direction, wind speed, temperature and humidity, and check that they
are within acceptable limits before spraying takes place. The operator should record wind direction, wind speed, temperature and humidity prior to and during every spray operation.

**Rainfall and irrigation**

It is important to time spray applications to avoid periods of rain or irrigation. Spraying onto leaves or other surfaces that are already wet dilutes most pesticide formulations and may lead to an increase in run-off, wasting the product and causing pollution. Wetting the sprayed surface after application can cause similar results depending on the ‘rain-fastness’ of the pesticide. Read product labels to determine appropriate practices. As a general rule, protectant pesticides (e.g. bordeaux mixture), which sit on target surfaces and contact pests directly remain vulnerable to washing off. Additives can be mixed with some formulations of pesticide to improve their durability on the target surface. Systemic pesticides are absorbed by plants if sufficient time for absorption is allowed prior to wetting and can remain active after wetting.

**Wind**

**Direction**

Droplets, particularly small ones, move with the air. Therefore, measuring the wind direction prior to and during application is essential. Importantly, the wind can be used to direct sprays away from identified susceptible areas. Do not spray when the wind is blowing towards susceptible areas.

Spraying should, where possible, be carried out with a crosswind, working into wind towards the unsprayed area (see adjacent diagram). All spray operators should be alert to changes in wind direction during spraying and modify or cancel a spray program as necessary.

**Wind speed**

Wind speed should be about 3–15 km/hr for most spraying operations. Droplets, particularly medium and large droplets, move greater distances in stronger wind conditions so some forms of pesticide drift can be reduced if application is undertaken during low wind speed conditions. However, spraying should not normally take place if the wind is light and variable in strength or direction.

**Temperature**

Whenever possible, spraying should be avoided in high ambient air temperatures. Water-based sprays are prone to evaporation, which decreases droplet size. Small droplets fall more slowly and may even remain suspended in the air, increasing the likelihood of drift and decreasing the amount delivered to the target. This is particularly true when air temperatures are high and the relative humidity is low. Initial droplet size may be increased to compensate for this, or an adjuvant can sometimes be added to the formulation to decrease evaporation. In open areas, high temperatures also mean the onset of unstable atmospheric conditions, which make it difficult to control the movement of droplets.
Humidity
Spraying of water-based sprays should not take place under conditions of high temperature and low humidity, i.e. when the wet bulb depression (a measure of evaporation potential) is greater than about 10°C. Thermometer-based whirling psychrometers or electronic hand-held instruments are available that can quickly assess relative humidity and temperature, both under shade structures and in the open.

Atmospheric stability
Stability is a term used to describe the vertical movement and mixing of air in the atmosphere (see figure 10). If the atmospheric conditions are unstable, such as occurs on a summer afternoon, the dispersion rate of pesticide sprays may be high. Spray droplets or vapours can be lifted up rather than settling, resulting in increased off-target drift.

In conditions of moderate stability where there is air movement, turbulence is created when air moves over the ground or plant canopy. This mixes air into the leaves of the plants and can assist in even delivery of pesticide droplets to targets within a leaf canopy.

Air moving slowly (less than 5–10 km/h) toward the target, without updraughts, represents ideal spraying conditions for many hydraulic spray operations.

Under very stable conditions with little air movement, such as very early mornings, large droplets fall more vertically and an increased proportion of pesticide is deposited on upper leaf surfaces. Without air movement to swirl them into the canopy, very fine droplets may even fall so slowly as to evaporate before impact and remain suspended in the air, leading to increased risk of drift during later air movement.

Temperature inversions
If the sky is clear at night, the ground can lose heat rapidly. The ground then cools the air layers adjacent to the soil surface, particularly if humidity (and thus heat capacity of the air) is low. Under these conditions, air close to the ground becomes cooler than air above. Since this phenomenon is opposite to the normal condition of the atmosphere (temperature decreasing with height), the condition is called ‘surface temperature inversion’.

Temperature inversions tend to suppress the vertical movement of air and therefore, in effect, present a

![Figure 10. Basic guide to air stability showing the behaviour of smoke or dust under various stability conditions](image-url)
barrier to the transport of small droplets to the crop canopy. Inversions usually form under very low wind speed conditions.

Spraying should be avoided under such circumstances, since small droplets are capable of remaining airborne for long periods after drifting above an inversion layer. This has been known to cause severe damage several kilometres away from where spraying took place.

Assessing conditions
Spraying should therefore ideally take place in neutral atmospheric conditions with slight air movement. The stability of the atmosphere can be assessed using smoke, or driving a vehicle along a dusty track. Movement of material up into the air indicates instability and concentration of smoke or dust within a thin layer indicates the presence of a surface temperature inversion.

3.4 Vegetative buffers
Trees and shrubs planted downwind of an agricultural area or nursery boundary can be used to capture droplets moving out of the sprayed area and thereby reduce spray drift. Their use has been trialled by several commercial nurseries.

Principles of buffers
If a dense barrier is presented to airflow, air tends to flow up and over the barrier. This is illustrated in figure 11a, where the airflow deviation over a solid board (0% porosity) placed in a wind tunnel is shown. The region directly behind the barrier is characterised by low pressure and turbulent eddies. Dense, low porosity structures are less effective in trapping the droplets moving with the air except in the immediate region behind the barrier because small droplets (under 100 µm) move readily in the airstream and are carried above and around the barrier.

A porous barrier, however, allows some air to pass through its structure while still deflecting some airflow over the top. This is illustrated in figure 11b where a nylon mesh with 50% porosity (50% solid and 50% open) was placed in a wind tunnel. The figure shows that there was less deviation of air over the top of the barrier compared to the solid barrier. The airflow behind the barrier was also straighter and less turbulent than behind the solid barrier. With a porous barrier, droplets can be carried through a buffer and this increases the chance of capture within the buffer.

Figure 11a and 11b. Effect of barrier porosity on airflow characteristics.
structure. A porous barrier can effect a greater removal of spray droplets than a solid barrier.

**Using vegetation as a buffer**

In designing vegetative buffers, the primary aim is to maximise the catching surface for the spray droplets while also minimising the amount of airflow passing around the buffer. This is not designed to be a complete windbreak, but more of a strainer or filter. The aim of a vegetative buffer is to use the natural surfaces (leaves, stems, flowers and seeds) of the trees or shrubs to catch pesticide droplets as they move in the air through the vegetation. Vegetative elements that present a small frontal area to the moving droplets are the most successful at catching droplets. Trees such as the river she-oak (Casuarina spp.) that have thin, needle-like foliage and numerous small branches are particularly suitable. Large leaves that are covered in small hairs can also be very efficient at removing droplets. Most natural surfaces are not smooth. Plants may have a complex rough surface comprising small protruding spikes or hairs and leaf veins. All these factors help to increase the catch efficiency of the plant. Movement of the leaves caused by the flow of air around shrubs and trees also increases the efficiency of small droplet capture.

** Constructed buffers**

Due to the intense land use of nurseries, it can be more convenient to erect artificial buffers using shade cloth and timber posts. These require no growing time and have the added benefit of retaining humidity and reducing the vulnerability of stock to wind damage. Contact your state Nursery Development Officer for information on construction details, or read the Nursery Paper *Windbreaks, an investment in quality and profitability*.10

**Height of buffers**

Because turbulence causes dispersion of a spray cloud, and it ‘spreads’ vertically as well as horizontally, a vegetative barrier must be higher than the release height of the spray. The greater the density of the buffer (the lower the porosity), the higher a barrier needs to be in relation to the spray release height. Wind tunnel tests have shown that the minimum height of the barrier should be at least one and a half (1.5) times the release height of the spray for a barrier with 50% porosity. If the porosity is reduced to 40%, the minimum height of the barrier increases to double (2 times) the release height.

For a solid barrier the required height approaches infinity, so solid barriers are not suitable unless they entirely enclose the sprayed area (as per a poly or glasshouse). As a general guide, the minimum height of the buffer should be double the release height (see figure 12). For example, if spraying is conducted by hand at a release height of one metre, then the buffer height should be at least two metres.

**Width of buffers**

The wider the buffer, the greater their ability to reduce spray drift. With a wide buffer it is possible to increase the number of surfaces available for droplet collection without significantly reducing the airflow through the buffer. A wide buffer is impractical in many rural–urban interfaces, so a compromise may sometimes be needed.

**Distance of buffers from spraying**

The closer the vegetative buffer is to the release point, the greater the proportion of spray that will be intercepted. Figure 13 shows that a vegetative buffer at position A would tend to intercept a greater proportion of a spray cloud than a buffer located at position B. However, the

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**Figure 12. Optimum vegetative buffer dimensions**
concentration through the spray cloud is not constant and usually tends to be greatest near ground level. A buffer at position B could still be expected to intercept a reasonable proportion of the airborne droplets.

Planning guidelines in Queensland

In 1997 the Department of Natural Resources in Queensland introduced the Planning Guidelines: Separating Agricultural and Residential Land Uses. The guidelines have the following objectives:

1. To protect the use of reasonable and practicable farming measures that are practiced in accordance with the Environmental Code of Practice for Agriculture and associated industry-specific guidelines.

2. To minimise scope for conflict by developing where possible, a well-defined boundary between agricultural and residential areas and not interspersing agricultural and residential areas.

3. To minimise the impacts of residential development on agricultural production activities and land resources.

4. To minimise the potential for complaints about agricultural activities from residential areas.

5. To provide residents with acceptable environmental conditions in residential areas that are located adjacent to agricultural production areas.

The Queensland guidelines specify a minimum spray drift buffer width of 20 metres planted with trees and at least 10 metres clear of vegetation to either side of the vegetated area to give a total buffer width of 40 metres. A schematic cross-section of this arrangement is shown in figure 14. A 20-metre clear area, (10 metres either side of the buffer) is included in the design to provide a fire break, allow access to the buffer for maintenance and limit solid structures immediately next to the buffer elements. Provided the requirements of the guidelines can be met by other means, the guidelines do allow buffer layouts to be altered. The Queensland guidelines provide a sound minimum basis for the construction of buffer areas between conflicting land uses.

Planning guidelines, an investment in quality and profitability

Figure 13. Effect of distance from release point

![Diagram showing effect of distance from release point](image)

Figure 14. Schematic illustration of vegetative buffer required for spray drift mitigation as defined by Planning guidelines: Separating agricultural and residential land uses (DNR 1997)
3.5 Spray drift strategy summary

In summary, operators can manage off-target movement of sprays in the nursery if they:

- Identify all areas around an area to be sprayed that could be susceptible to spray drift damage.
- Communicate on a regular basis with neighbours regarding proposed spray schedules and activities.
- Maintain a copy of relevant safety data sheets (SDS) for all pesticides stored and used.
- Read, understand and follow the pesticide product label prior to mixing and spraying.
- Observe and record wind direction, wind speed, temperature and humidity prior to and during application.
- Avoid spraying when air is moving toward susceptible areas.
- Avoid spraying if the wind is light and variable in strength or direction.
- Spray water-based sprays when temperatures are the lowest (in a 24 hr cycle).
- Avoid spraying water-based pesticides under conditions of high temperature and low humidity.
- Spray when atmospheric conditions are neutral.
- Avoid spraying during highly stable conditions or when surface temperature inversion exists.
- Spray with a crosswind and progress upwind.
- Ensure spray equipment is correctly calibrated and appropriate nozzle systems are selected.
PESTICIDE APPLICATION
EQUIPMENT AND
TECHNIQUES

A wide variety of pesticide application equipment is available. Assess the suitability of the equipment for the specific task and choose appropriate application techniques.

4.1 Sprayer types
Sprayers used in plant nurseries are commonly classified according to the volume of spray they apply per sprayed area. Application type and delivery volumes are determined by the choice of nozzle. It is the nozzle that delivers the spray solution as spray droplets are distributed over the treatment area.

Nozzle selection is one of the most important considerations when selecting a sprayer. In this manual, nozzle types have been separated into three categories according to the way they are used when fitted to pesticide application equipment used in nurseries: 1. high volume, 2. low volume and 3. ultra low volume.

High volume
High volume sprayers are the most common types of sprayer used in nursery operations. Application rates range from about 200 L/ha to over 2000 L/ha. High volume sprayers are typically used where the label refers to spraying to run-off. Hydraulic nozzles such as flat fan and hollow cones or adjustable hand guns are typically used on high volume sprayers. These sprayers may range from small units such as the Silvan Selecta® range, up to large, purpose-built units such as the QuikSpray 9TBE®.

Low volume
Low volume sprayers are used as an alternative to high volume hydraulic sprayers for pesticide application in plant nurseries, particularly where label rates are expressed as a volume of chemical per unit volume of spray solution (e.g. 300 mL per 100 L of water). Although they may be more expensive, they may also provide better target coverage. Some low volume sprayers may also reduce the time required for spraying and, therefore, cost of labour. Low volume equipment typically uses
air-shear or spinning discs (commonly referred to as CDA or ‘controlled droplet applicator’ nozzles) to generate droplets. Examples of air shear include the Silvan Turbomiser® and the Hardi® backpack mister. The ULVA+® and Herbi4® sprayers are examples of CDA technology.

**Ultra low volume**

Ultra low volume sprayers used in nursery applications are commonly called foggers and they apply very low volumes (less than 10 L/ha) of chemical mix. In some cases, the pesticide is applied neat or directly from the container without any mixing with water. The use of ultra low volume systems is only possible if the spray is delivered as very small droplets. Examples include the Curtis Dyna-Fog® and the pulsFog®.

### 4.2 Sprayer components

Sprayers come in a large range of types and sizes, from small, hand-held sprayers to large, self-propelled machines. While there is such a large variety, there are some basic components that are found on nearly all types of sprayers (see figure 15). The basic components used in liquid application systems include:

- nozzles to generate droplets
- a method of holding the nozzle so that the spray is directed towards the target (e.g. boom)
- a frame or chassis and drive
- a tank to hold the chemical
- a method to make liquid flow (e.g. pump)
- an agitation system to keep the spray solution well mixed
- pressure regulators and control valves
- a filtration system (suction and pressure in-line filters)
- auxiliary equipment, such as a clean water tank, diaphragm check valves and spray management valves.

![Diagram of spray system](image_url)

**Figure 15. A typical layout of application equipment (high and low volume) used in the nursery industry**
Tank

The spray tank should be of an appropriate size for the type of sprayer used and the volume of pesticide mixture required for the area to be sprayed. The shape of the tank should allow for easy access for filling and ease of drainage and cleaning. A small sump in the tank is generally recommended so that a minimum amount of liquid remains within the tank after the majority of the spray solution has been used.

Materials used in tank construction need to be resistant to chemicals, non-corrosive, not easily damaged, resistant to sunlight and easy to repair. A gauge showing volumes at various percentages of fill is important.

Pump (liquid flow)

The spray liquid is usually forced through the nozzle using a pump to generate pressure. Some hand-held systems such as the ULVA® and HERBI® use gravity for the liquid to flow (tank positioned higher than nozzle). A wide variety of pumps are available for application systems. Examples include diaphragm, centrifugal, piston, roller, and gear pumps. Pumps used in nursery situations are commonly powered by a 12 V battery, a separate petrol motor on the sprayer or a tractor driven power take-off (PTO).

When selecting a pump, the following factors should be considered:

- the operating pressure required
- the output (L/min) of liquid required
- power requirement to drive the pump
- type of chemicals to be used
- durability of the pump
- costs.

Agitation system

Many chemical formulations consist of fine powders or particles that need to be held in suspension in the chemical mix. If the mix is left to stand, these particles may settle on the bottom of the tank. A system to agitate or mix the chemical is therefore required. This is usually achieved by recirculating some of the spray mix back to the spray tank. The pump output should be greater than that required to operate the nozzle to allow recirculation back into the tank during spraying. Once flow to the nozzles is stopped, the total flow from the pump is redirected back into the spray tank. Sometimes special fittings are used on the bypass system to increase the agitation in the tank.

Other methods of agitation include mechanical systems, such as a rotating paddle, or manual agitation, by physically shaking the tank of small hand-held equipment. Pesticide labels should always be consulted to determine any specific requirements for agitation.

Pressure regulators and control valves

Liquid flow rate and pressure to nozzles must be controlled to ensure that sprayer output is consistent. This is generally achieved by use of pressure regulators and/or control valves. These may be operated manually or electronically, particularly for the larger sprayers. All systems MUST be fitted with a pressure gauge. The gauge should be positioned as close as practicable to the nozzles and be clearly visible to the operator. On tractor mounted equipment, two separate pressure gauges may be necessary, one visible to the operator and the other nearer to the nozzles used for calibration and set-up of equipment.

Filtration system

Filters are required to prevent nozzle blockage. Blockage results in wasted time, increased risk of chemical exposure if nozzles or filters require cleaning in the field and poor coverage in the field if individual nozzle blockages are not detected. Factors such as the water source, pesticide formulation and pump agitation capability influence the type of filtration system required for the sprayer.

There are typically several stages of filtration in liquid application equipment. These stages and typical mesh sizes are listed below. Mesh size is defined as the number of openings along a linear inch. Thus 100 mesh has 100 openings along a linear inch, or 10 000 openings per square inch.

<table>
<thead>
<tr>
<th>Filter stage</th>
<th>Typical mesh size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank inlet filter</td>
<td>50 mesh</td>
</tr>
<tr>
<td>Suction filter</td>
<td>40–80 mesh</td>
</tr>
<tr>
<td>Pressure line filter</td>
<td>40–80 mesh</td>
</tr>
<tr>
<td>Nozzle filter</td>
<td>50–100 mesh</td>
</tr>
</tbody>
</table>

For hydraulic nozzle operation, the manufacturer’s recommendations should be followed. The fitting of pressure in-line filters with easy access and colour-coded filters is recommended. For positioning of the pressure in-line filter, refer to figure 15.
Auxiliary equipment

Auxiliary equipment such as a fresh water tank and chemical handling equipment can be added to a sprayer system for increased safety and easier preparation of chemicals. Smaller chemical tanks such as chemical induction hoppers can be added to the side of the larger tanks at an accessible height to allow safe pouring of chemicals. Clean water tanks are important for hand washing and use in emergencies when clean water may be unavailable in the field.

4.3 Spraying equipment

Symbols describing spraying equipment

To assist in ease of use and economy of space within the manual, symbols have been used to indicate certain aspects of spray application. These symbols are listed and described below and on page 2. The symbols have been included with the general descriptions and advantages and disadvantages of each piece of pesticide application equipment described in this chapter.

Where one or more symbols have been included with the description of the equipment, this indicates that this piece of equipment is suitable for the use or uses that each of those symbols indicates.

For instance, some sprayer types are suitable for use at a range of volumes and may have all three sprayer type symbols included with their descriptions, whereas others may only be suitable for use at one volume, such as many of the ultra low volume sprayers. Some sprayers may produce a wide range of droplet sizes, while others may produce a narrow range of droplet sizes.

Some sprayers will be useful in a range of nursery operations, whereas others may be limited to glasshouse, polyhouse or outdoor use.

The symbols are used to indicate what sprayer type, droplet size, pesticide type, nursery design, expected coverage and nursery size may be suitable for each type of application equipment discussed.

If in doubt about any of the symbols used in this chapter, please refer back to this key.

Always refer to the manufacturer’s catalogue when selecting or fitting appropriate accessories such as nozzles, handpieces, etc for pesticide application.

Be sure to check the output and nozzle specifications to ensure that they are appropriate for the task intended.

Key to symbols used in this manual

Sprayer type

- Ultra low volume
- Low volume
- High volume

Droplet size

- Fine and very fine
- Medium
- Coarse

Coverage

- Spot spray
- Blanket spray

Pesticides

- Fungicides
- Herbicides
- Insecticides

Nursery design

- Open plan
- Shade house
- Glasshouse

Nursery size

- Small
- Medium
- Large
Hydraulic nozzles come in a wide variety of designs. Droplets are formed by forcing the spray liquid under pressure through specially designed holes, or ‘orifices’, in the body of the nozzle. The most common types of hydraulic nozzles are the flat fan and hollow cone nozzles. The spray patterns produced by these two nozzle types are shown in the diagrams below. In general, flat fan nozzles produce a slightly larger droplet size than the hollow cone nozzle and can be operated at lower pressures than hollow cone nozzles.

The droplet size produced by hydraulic nozzles increases as the orifice size is increased (allowing higher flow rates) or as the operating pressure is decreased. Decreasing pressure also decreases the angle of the spray pattern.

Most manufacturers of hydraulic nozzles now produce low drift nozzles that are designed to produce larger droplet sizes under typical operating conditions. The larger droplet sizes can assist in reducing drift, but may also reduce coverage on plant surfaces due to the lower number of droplets that are generated per volume of spray liquid. Drift reduction nozzles produce larger droplets through minor changes to the nozzle design. Typically, these changes are in the form of a pre-orifice or by air inclusion in the liquid.

Hydraulic nozzles are usually mounted at or near the end of a hand lance or hand gun, or along a boom.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• versatile</td>
<td>• difficult to get uniform coverage</td>
</tr>
<tr>
<td>• low cost</td>
<td>• nozzles are prone to wear</td>
</tr>
<tr>
<td>• nozzles are easy to use—no moving parts</td>
<td>• nozzles require regular calibration</td>
</tr>
<tr>
<td>• nozzles can be used for a wide range of situations</td>
<td>• pressure and distance to target must be known</td>
</tr>
<tr>
<td>• nozzle components are easily changed</td>
<td>• air assistance is sometimes required for efficient small droplet capture on targets</td>
</tr>
<tr>
<td>• parts are of a simple design</td>
<td>• nozzles generate a wide droplet spectrum that can lead to wastage and/or pesticide drift</td>
</tr>
<tr>
<td>• the wide droplet spectrum allows for some operator error</td>
<td></td>
</tr>
</tbody>
</table>
The hand gun is the most commonly used spray nozzle in nursery situations. They are usually operated at a high pressure of 10–30 bar (150–450 psi), although lower pressure versions are available. Due to this high pressure, hand guns are able to throw the spray liquid long distances, which enables the operator to stand in walkways and direct the spray to the far side of racks or bays. However, this increased throwing distance encourages the production of large droplet sizes. These large droplets may lead to poor coverage, particularly on lower leaf surfaces, excessive use of pesticide mixture, run-off and contamination of the environment. The use of too high a pressure can also result in very fine droplets being produced (misting). These fine droplets are prone to drift away from the application area and may also contaminate the operator. The high pressure may also result in damage to foliage nearest to the release point from the hand gun.

Spray guns may have either a fixed swirl chamber or an adjustable swirl chamber that allows a change of spray angle and thus the spread of the spray. Adjustable nozzles can provide spraying flexibility, however a greater degree of operator knowledge is required to correctly use these nozzles. Changes to flow rate, operating pressure, width of the spray, throwing distance and droplet sizes will all influence the effectiveness of pest management. For details of these influences refer to chapter 3 of this manual.

The trigger on adjustable nozzle guns allows the operator to change the flow rate and nozzle performance. While this has practical advantages, it makes these systems difficult to calibrate when using products that need to be applied on a volume per unit area basis (e.g. L/ha) rather than a volume per volume or concentration basis (e.g. 300 mL per 100 L of spray solution).

Sprayer units fitted with a high-pressure hand gun can be mounted on tractors, trailers or hand-pushed carts, which increases manoeuvrability. One significant disadvantage of the hand gun is that the coverage is dependent upon the individual spray operator. Some product labels recommend that the volume of spray has to be applied until run-off occurs on the plant. This definition of ‘run-off’ is an ambiguous term and the amount applied by different operators can vary considerably across a target area. Run-off also results in loss of spray into the environment.

**Advantages**
- versatile—can be used for all spraying operations
- nozzles may be adjusted to suit operating conditions
- relatively inexpensive
- can be used in various sizes of nursery

**Disadvantages**
- difficult to calibrate
- highly subject to operator error
- difficult to achieve uniform coverage
- high risk of run-off and environmental contamination
NOZZLES: LOW VOLUME

Air shear sprayers

Air shear nozzles use high-speed air (up to 300 km/hr) to convert the spray solution into droplets. The spray liquid is fed at low pressure to the nozzle through a suitable restrictor and the jet of liquid emerging at the nozzle orifice is then sheared by the high speed air into droplets that are carried to the target in the air stream produced by the sprayer.

Droplet sizes generated from air shear nozzles are usually fine to very fine. The most important variable determining droplet size is the air:liquid ratio. Larger droplets are obtained with increased liquid flow and/or through a reduction in air velocity. The spray liquid should be spread into a sheet to maximise the effect of airflow and obtain efficient break-up into droplets. Variation in droplet size depends to some extent on the design and position of the spray liquid orifice in relation to the airstream.

Air shear systems may have a high power requirement because of the need to produce high-speed air for the efficient formation of small droplets. Such systems range from backpack misters to large tractor powered units such as the Turbomiser®. Hearing protection is generally required when operating these systems due to the noise generated by the motor and fan. Newer models of backpack misters tend to be quieter and may be preferable to older models.

The air used in the production of the droplets can also be used to constrain droplets within the airstream and to direct the droplets towards the target. This can increase the droplet capture and coverage on the target. Various deflectors and diffusers can be used to manage and direct the droplet-laden air to the targets.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• small droplets can result in good coverage under suitable conditions</td>
<td>• cost of equipment</td>
</tr>
<tr>
<td>• air movement can aid penetration into canopy and droplet capture on targets</td>
<td>• high level of operator knowledge required</td>
</tr>
<tr>
<td>• spray covers a large area quickly</td>
<td>• small droplets are prone to drift</td>
</tr>
<tr>
<td>• changing air/liquid flow can alter droplet size</td>
<td>• high power requirement</td>
</tr>
<tr>
<td>• low quantities of carrier fluid required</td>
<td>• not suitable for spot spraying</td>
</tr>
<tr>
<td></td>
<td>• can be noisy</td>
</tr>
</tbody>
</table>
Controlled droplet application (CDA) is a method of producing droplets using spinning discs or cages. CDA sprayers produce a narrower range of droplet sizes compared to hydraulic nozzles. The droplet sizes produced by CDA sprayers can be increased or decreased by changing the rotational speed of the disc or the flow rate of the liquid, or a combination of both. The selection of the disc or cage type is also important for managing droplet size.

Rotational speed for battery operated equipment, such as the Herbi 4® or ULV A® CDA sprayers can be affected by the number of batteries or the charge of the batteries. Flow rate can also be affected by the viscosity of the liquid. In some models the flow rate can be changed by changing the metering orifice.

- To produce smaller droplets—increase rotational speed, or decrease flow rate, or a combination of both.
- To produce larger droplets—decrease rotational speed, or increase flow rate, or a combination of both.

For optimum outcomes and management of the droplet sizes, refer to the manufacturer’s handbook. The selection of disc or cage types is important in managing the droplet spectrum produced by the sprayer.

Small discs spinning at high speeds can produce fine droplets that considerably increase the target coverage when applying insecticides and fungicides. Many of these systems, such as the ULV A +®, use a fan with the spinning disc to direct droplets towards the desired target. This can further increase coverage by improving penetration and target capture of the spray droplets. ULVAs have smaller discs that spin at higher speeds and are better suited to insecticide and fungicide operations in controlled environments such as glass or polyhouses. Herbis, on the other hand, have larger discs that normally spin at lower speeds and produce larger droplets. They are typically used for herbicide application.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• a narrow range of droplets can be produced</td>
<td>• most nozzle systems require relatively complex motorised components</td>
</tr>
<tr>
<td>• uniform droplet size</td>
<td>• for effective use, specialist knowledge and a high level of understanding is required</td>
</tr>
<tr>
<td>» Herbi® units minimise small droplets (minimising drift)</td>
<td>• accurate droplet formation requires the correct disc or cage, rotational speed and liquid flow rate</td>
</tr>
<tr>
<td>» ULV A+® units minimise large droplets (minimising waste and carrier volumes)</td>
<td>• may be difficult to calibrate, as swath width may vary depending on wind conditions and operating height</td>
</tr>
<tr>
<td>• air assistance can be used to increase coverage/penetration</td>
<td>• battery driven models may need regular recharging or battery replacement</td>
</tr>
<tr>
<td>• nozzle systems can be tailored for the production of certain droplet sizes (e.g. high speed small discs produce fine droplets, low speed large discs generate larger droplets)</td>
<td></td>
</tr>
<tr>
<td>• generally light weight and low energy use</td>
<td></td>
</tr>
</tbody>
</table>
In electrostatic sprayers the spray material is given a static electric charge as it travels through the nozzle. In theory this can help to create droplets that are more uniform in size, which disperse more evenly because they repel each other, since all droplets carry a like charge.

Several styles of electrostatic sprayers are available. They require an independent power supply to charge the tank. Other units are cart-mounted with an integral compressor powered by a petrol engine or electric motor. Electrostatic sprayers work best if the sprayer-to-target distance is less than 4–5 m.

Penetration of spray into a dense canopy and coverage onto the under leaf surfaces can be poor because the droplets are attracted to the nearest surface, which may well be the outer foliage of the plant. Electrostatic charging is only effective for small droplets. The charging may also not be sufficient to overcome other effects such as wind, so they are best used in controlled environments such as glasshouses or polyhouses.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• small droplets potentially give a more uniform coverage on both upper and lower leaf surfaces</td>
<td>• high operator hazard as spray can be attracted to operator and equipment</td>
</tr>
<tr>
<td></td>
<td>• very high level of knowledge required for successful use</td>
</tr>
<tr>
<td></td>
<td>• high level of maintenance</td>
</tr>
</tbody>
</table>
Cold foggers, also known as mechanical foggers, use high-pressure pumps and atomising nozzles to produce very small fog-sized particles of less than 15 µm. Distribution of the spray material is through a hand-held gun or external fan unit. With the fan unit, the distance and the area that can be treated depend on the capacity of the fan. Multiple units or multiple settings may be needed to cover large areas.

Often it is difficult for fine droplets to penetrate dense canopies, however, many studies have shown good pest management has been achieved using foggers.

Safety is important when using a mechanical fogger employing a high-pressure pump. Hands and arms must be kept away from the outlet because at 2000–3000 psi spray particles can penetrate the skin very easily. Information should also be gathered on the length of time that fog stays suspended in a still or controlled environment to determine the period for safe re-entry to the area.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• blanket spray</td>
<td>• drift</td>
</tr>
<tr>
<td>• suitable for glasshouse/polyhouse application if appropriate products are used</td>
<td>• operator hazard</td>
</tr>
<tr>
<td>• very small droplets can result in good coverage</td>
<td>• can’t spot spray</td>
</tr>
<tr>
<td></td>
<td>• small droplets may not penetrate dense plant canopies</td>
</tr>
</tbody>
</table>
NOZZLES: ULTRA LOW VOLUME

Thermal foggers

Thermal foggers require a specially formulated carrier that is mixed with the pesticide to improve uniformity of droplet size and distribution of the spray material. The carrier also decreases molecular weight, allowing the particles to float in the air for up to six hours without settling or evaporating. This means the spray is able to penetrate far into the structure rather than settling near the spray unit. This can be a disadvantage when access to the treated area is required. Venting of the treated area before access must be considered.

A thermal fogger uses a system similar to that used in jet engines. The pesticide is injected into the extremely hot, fast moving air stream, where it is vaporised into fog-sized particles. Moving from one end to the other, a hectare can be covered in as little as 30 minutes.

Air circulation systems in a building will improve the uniformity of coverage and foliage penetration.

The temperature and humidity in the greenhouse can also affect the spray droplets. Under high temperatures and low humidity, the spray droplets will tend to fall out of the air quicker and increase the level of deposits on the upper leaf surfaces.

Due to the level of noise generated by thermal foggers, hearing protection should be worn when using this equipment.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• blanket spray</td>
<td>• drift</td>
</tr>
<tr>
<td>• suitable for glasshouse or polyhouse use</td>
<td>• operator hazard from small droplets and noise</td>
</tr>
<tr>
<td>• very small droplets can result in good coverage, particularly when combined with air movement</td>
<td>• spot spraying is impossible</td>
</tr>
<tr>
<td>• saves time in spraying</td>
<td>• small droplets may not penetrate dense plant canopies without air movement</td>
</tr>
</tbody>
</table>
NOZZLES: OTHER

Wick wipers

Rope wick applicators are a convenient way of applying herbicides to manage weeds in plant nurseries. They produce no drift and therefore can be used close to other plants. They are ideal for weed management on paths, particularly in retail situations where the opportunities for spot spraying may be limited.

Rope wick applicators are used for wiping translocated herbicides (e.g. glyphosate) onto the foliage of susceptible weeds. They consist of a container from which the pre-mixed spray solution is able to soak an absorbent surface without dripping excess liquid.

The main problems with wick wipers are the difficulties in avoiding dripping, or conversely, having too dry a wick, and accumulation of dirt on the surface of the applicator. The hand-carried rope wick applicator is mainly used for spot treatment of weeds on paths and between beds where the likelihood of the wick contacting nursery plants is minimal.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• no drift</td>
<td>• translocated herbicides only</td>
</tr>
<tr>
<td>• low cost</td>
<td>• products recommended for use in wick wipers are usually non-selective</td>
</tr>
<tr>
<td>• easy to use</td>
<td></td>
</tr>
</tbody>
</table>
NOZZLE HOLDERS : HYDRAULIC SPRAYERS

On many nursery sprayers the nozzle-holding device is hand-held by the spray operator. Nozzle-holders can incorporate structures such as shields to minimise drift or otherwise modify the spray pattern and management (e.g. diaphragm check valves).

**Hand-held nozzles**

![Image of hand-held nozzles]

For most sprayers used in nursery situations the nozzle is held by hand and manually directed towards the target. The nozzle may either be a hydraulic hand gun or hydraulic nozzle at the end of a lance. More than one hydraulic nozzle may be used on a small boom arrangement. They usually have a trigger or tap to enable the operator to quickly and easily start and stop liquid flow to the nozzle.

The nozzles can be at the end of a long flexible hose connected to the remainder of the sprayer components, which can then be parked at a convenient location. This approach allows greater freedom for the operator to move around the nursery. The hose is usually manually rolled and unrolled but some units (e.g. QuickSpray®) have a radio controlled unit to remotely coil and uncoil the hose.

When applying the pesticide mixture to the target, the operator needs to carefully move the nozzle in such a way that uniform coverage of the target is achieved over the entire treatment area.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• flexible operation—able to manoeuvre around nursery structures such as irrigation risers and building supports</td>
<td>• difficult to calibrate</td>
</tr>
<tr>
<td>• operator exposure due to direct handling of nozzle and hoses</td>
<td>• uniform deposits difficult to achieve</td>
</tr>
</tbody>
</table>
Vehicle-mounted boom sprayers can be used to treat larger areas within the nursery more uniformly than is possible with hand-held equipment.

A boom is a structure on which more than one nozzle is mounted. The boom is usually attached to the other components and driven along roadways with the boom directed over the target area (plant bed). Most booms are mounted at the rear of the spray tank, although some are in front so that the operator can see the position of the nozzles in relation to the rows. The front mounted boom position can result in increased risk of operator exposure to the pesticides.

For nursery sprayers a single-, or occasionally, a double-wing boom is used. During spraying, the outer sections are often mounted so that they can be moved out of the way of any obstructions. Manufacturers have used various methods to pivot and fix the boom sections for easy handling. Normally, the booms are unfolded by hand, but on some sprayers, positioning of the boom can be managed hydraulically without the operator leaving the tractor or vehicle.

A wide range of hydraulic nozzles can be fitted to the boom. The nozzle body may be screwed into openings along the boom, but often the boom incorporates special nozzle bodies clamped to the horizontal feed pipe. A diaphragm check valve should be used with each nozzle to prevent dripping of liquid when pressure to the boom is low (i.e. the vehicle is stationary). Nozzles are evenly spaced along the boom and the height of the boom should be adjusted according to the type of nozzle being used and the manufacturer’s recommendations.

The pattern from each nozzle has to be overlapped to achieve as uniform a distribution of spray as possible across the whole boom. Some operators use a double overlap. If the boom is set too high drift potential is increased and excessive overlap can occur, resulting in very uneven distribution. The subsequent ‘peaks’ and ‘troughs’ occur with both fan and hollow cone nozzles, but are generally more pronounced with hollow cone nozzles. Uneven distribution also results if the boom is set too low.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• quick to cover the target area</td>
<td>• booms can be difficult to manoeuvre around the nursery (e.g. irrigation risers, building structures)</td>
</tr>
<tr>
<td>• greater uniformity in deposition than hand guns</td>
<td>• nozzles wear and should be replaced regularly</td>
</tr>
<tr>
<td>• nozzles can be changed to suit situation</td>
<td></td>
</tr>
</tbody>
</table>
NOZZLE HOLDERS (VEHICLE-MOUNTED)

Vertical booms

A vehicle mounted boom fitted with controlled droplet applicator (CDA) heads has various names including ‘vertical boom’ and ‘vertical mister’. Each head consists of four spinning discs and a fan. These are driven by hydraulic pressure generated by a pump under the tank that attaches to the tractor’s power take-off (PTO). The heads are normally operated at around 2000 rpm to generate droplets that are then moved toward the target in the air-stream created by the fans.

Heads can be fitted facing forward or backward to suit the orientation of the target. The entire unit, including tank, is usually mounted on the three point-linkage of a small tractor.

When using vertical booms care must be taken to determine that the fans create sufficient air movement so that spray droplets penetrate into the plant canopy. This is an important part of calibration with this equipment.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• quick to cover the target area</td>
<td>• tractor mounted equipment can be difficult to manoeuvre around the nursery</td>
</tr>
<tr>
<td>• greater uniformity in deposition than hand-held CDA equipment</td>
<td>• risk of drift if airflow not entirely intercepted by target</td>
</tr>
<tr>
<td>• attitude and airflow can be adjusted to suit target</td>
<td>• greater requirement for operator knowledge</td>
</tr>
<tr>
<td></td>
<td>• difficult to spot spray small areas</td>
</tr>
</tbody>
</table>
NOZZLE HOLDERS

**Shielded sprayers**

Shields are sometimes placed around the spray nozzle to prevent droplets (usually of herbicide) travelling away from the target area. With sprayers generating air movement they may also be used to direct droplets in the air stream toward the target. This technique is particularly suited for weed management around the nursery such as weeds growing in walkways and near buildings.

Shielded sprayers can be suitable for applying non-selective chemicals because they can minimise the off-target losses. When shields are fitted to knapsack sprayers a flat fan nozzle should be used, with a spray angle that is appropriate for the shield design. Even when using a shielded sprayer the correct hydraulic nozzle should be selected for the target, only spray during suitable conditions and operate at a pressure that minimises the formation of small droplets.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• low drift</td>
<td>• generally not used for insecticide/fungicide application to plant nurseries</td>
</tr>
<tr>
<td>• suitable for herbicide application</td>
<td>• large units can be relatively expensive</td>
</tr>
<tr>
<td>• can decrease chemical use by spot spraying</td>
<td>• the weight of the shield on hand-held units</td>
</tr>
</tbody>
</table>
FRAME/CHASSIS AND DRIVE

The sprayer requires some form of frame or chassis to hold all the sprayer components together. This needs to be of sufficient strength to carry the load (including a full spray tank). A method of driving the sprayer over the treatment area is also required. This can be achieved by foot, tractor, 4WD motorbike or self-contained drives.

Trailers

Trailer sprayers come in a large variety of sizes and shapes. The size of the trailer typically relates to the area requiring treatment. The larger the area, the larger the spray components and hence, the larger the trailer. Trailer sprayers are often fitted with one or more hydraulic hand guns or a wand on a short boom fitted with nozzles.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• versatile</td>
<td>• difficult to turn in small areas</td>
</tr>
<tr>
<td>• flexible</td>
<td>• bulky</td>
</tr>
</tbody>
</table>
FRAME/CHASSIS AND DRIVE

**Tractor three-point linkage mounts**

The entire sprayer unit may be mounted on the three-point linkage of a tractor. This method is more common in large nurseries. The Silvan Turbomiser® is a commonly used example of a tractor-mounted droplet delivery system. The same principles apply as with smaller scale equipment. In this case, as an air shear sprayer, it is not suitable for herbicide application because of the large number of small droplets produced that create a high potential for drift.

Tractors can be fitted with cabins and suitable air filters to decrease operator exposure to pesticides during application.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• quicker to cover large target areas</td>
<td>• only suitable for larger operations</td>
</tr>
<tr>
<td>• small droplets in a moving airstream can improve target capture</td>
<td>• may require more horsepower to operate than available on many small tractors</td>
</tr>
<tr>
<td></td>
<td>• drift needs to be considered</td>
</tr>
</tbody>
</table>
Knapsack sprayers are carried by the operator, usually on the back. The pump is usually a piston or diaphragm driven by a lever that the operator moves up and down during use. Small petrol motor-driven pumps or electric pumps operating on a rechargeable 12V battery may be used on some units. Most lever-operated knapsack sprayers are fitted with a simple lance with usually one or two nozzles at the end. Hydraulic nozzles are typically used.

When using lever-operated knapsacks, the operator works the pump several times with the tap closed so that pressure is built up in the pressure chamber. The tap is opened and the operator continues to pump steadily with one hand while spraying with the other. Ideally a pressure control valve is also fitted adjacent to the tap. Spray management valves (SMVs) can be fitted to ensure that the pressure at the nozzle remains constant. Most older-style knapsacks deliver low pressures of 1–5 bar, but some newer models are capable of 8–9 bar.

Compression sprayers

Some units have a small tank that can be carried by hand or slung over the shoulder by a strap. These are referred to as compression sprayers. A hand pump, usually built into the tank, is used to pressurise the tank to a level suitable for correct operation of the nozzle. An SMV should be fitted to ensure constant pressure during spray operations. A pressure relief valve should also be fitted into these sprayers to release pressure for refilling.

All systems that rely on manual pumping suffer from fluctuating pressure levels. The operator may over-pump the sprayer and create excessive pressure or may under-pump, which results in insufficient pressure being produced. These changes in operating pressure alter the flow through the nozzle and therefore the droplet size generated. A constant pressure SMV positioned just before the nozzle can overcome these variations in pressure.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• suitable for spot spraying</td>
<td>• operator hazard—may leak, weight on back</td>
</tr>
<tr>
<td>• for small operations</td>
<td>• variable pressure (unless SMV used), variable flow rate</td>
</tr>
<tr>
<td>• a range of nozzles can be used for target and pesticide combinations</td>
<td>• must be calibrated for each operation</td>
</tr>
</tbody>
</table>
The objective when applying pesticides is to deliver the required amount of active constituent of the chemical to the desired target area. Regular calibration allows the operator to check that each of the components of the sprayer is operating within acceptable limits. It will also prevent over-dosing or under-dosing the target areas and reduce unnecessary contamination of the environment.

Over-dosing occurs when more than the recommended amount of a pesticide or mixture of pesticides is applied to the target area. This can result from hydraulic nozzle wear and other faults, such as increased pressure and varying travel speed, resulting in increased flow rates.

Over-dosing results in:
- wasting pesticides or products, time and money
- possible damage to crops (phytotoxicity)
- the possibility of exceeding the product’s maximum residue limit (MRL)
- extra wear and tear on equipment
- possibly reducing the effectiveness of the product
- increased risk to non-target area
- increased risk of developing pest resistance to pesticides.

Under-dosing occurs when less than the recommended amount of active constituent is delivered to the target. This can be caused by blocked nozzles or filters and varying travel speed. This problem is difficult to detect with the eye and often goes unnoticed until a major blockage occurs.

Under-dosing results in:
- wasting chemicals, time and money
- reduced effectiveness of the product or pesticide
- increased risk of development of resistance to insecticides and fungicides
- possible production losses due to pest damage or competition.

Regular calibration of equipment will help to identify and reduce these problems.

Do not rely on experience to know how far a tank will spray.

Equipment calibration is the only way to check the sprayer’s application rate per area and identify problems in the uniformity of output.

5.1 Calibration technique
Calibrating a piece of equipment for the application of pesticides as droplets involves four steps. These four steps are used in calibrating all types of sprayers, including hand-held equipment, boom sprayers, air-assisted hydraulic and air shear sprayers, misters and even agricultural aircraft. The form used by Nursery & Garden Industry Queensland is provided on page 68 to assist with the relevant calculations. The basic principles of calibration are discussed for collecting information. In the final section, these principles are applied to the major types of equipment.

It is important that accurate records are kept of the calibration process.

Before commencing calibration
It is important to ensure that the sprayer is operating correctly before taking any measurements of the sprayer’s performance. The equipment must be checked and adjusted if necessary before calibration. The operator or supervisor should check the:
- the sprayer is clean
- the pesticide label recommendations in relation to rates and safety requirements
- the pressure gauge is operational (if fitted)
- pressure regulator setting (if one is fitted)
- spray lines and filters for leaks, blockages
- nozzle and sprayer description
- environmental conditions
- equipment is the most suitable for the job.

**Steps for generalised sprayer calibration**

**A. Measure sprayer output (L/min)**
The sprayer output is calculated by collecting and measuring the output of the nozzle(s) at the operating pressure required, into a container for one minute. The output from all nozzles should be measured. To reduce any errors, this procedure should be performed at least three times, then an average reading calculated.

The measured output of a nozzle is only acceptable if it varies by less than 10% from the manufacturer’s new nozzle specifications. If the measured output of a nozzle varies by more than 10% from the manufacturer’s new nozzle specifications, that nozzle should be replaced.

Enter the result at A on the calibration sheet (page 68).

**B. Calculate the area sprayed in square metres per minute (m²/min)**
Calculating the area sprayed during the calibration requires two activities:
1. The first information required is the sprayer/nozzle’s swath width in metres. Swath width is the width of spray coverage that is effectively delivered by the nozzle(s) to the target area, i.e. how wide the sprayer can effectively spray. For many plant nursery situations, the swath width can be taken as the width of the beds being sprayed.
2. The second measurement is the distance travelled (in metres) by the sprayer during one minute (see diagram below). This is measured while actually spraying with water.

The area sprayed in metres squared per minute (m²/min) is calculated from the swath width and distance travelled using the formula on the calibration sheet.

Enter the result at B on the calibration sheet (page 68).

**C. Calculate the sprayer’s application rate in litres per hectare (L / ha)**
This step determines the sprayer’s output over a given area. For liquids this is known as the application rate in litres per hectare (L/ha). Registered pesticides must be applied at the application rate specified on the label. The sprayer application rate is calculated by using the data collected in steps A and B.

Enter the result at C on the calibration sheet (page 68).

**D. Calculate the amount of chemical required per spray tank volume**
This is a critical step in the calibration procedure, as it ensures that the recommended label rates of pesticides are applied to target areas by determining the amount of chemical to be added to the spray tank to make up the volume that is to be used.

To calculate the amount of pesticide to add to the required tank volume the following information is needed:
- Sprayer application rate (L/ha) (calculated in step C)
- Registered product label rate (L/ha or g/ha or kg/ha or L/100 L or g/100 L or kg/100 L as stated on the label)
- Tank volume (L) for the amount of spray being prepared.

Enter the result at B on the calibration sheet (page 68).
CALIBRATION SHEET

APPLICATION RATE

\[ A = \text{LIQUID FLOW (NOZZLE OUTPUT) FOR 1 MINUTE} \]

\[
\text{NOZZLE OUTPUT/FLOWRATE} = \text{[............]} \text{ L/Min (A)}
\]

\[ B = \text{AREA (WIDTH X DISTANCE)} \]

\[
\text{WIDTH (SWATH WIDTH)} = \text{[ ]} \text{ (W)}
\]

\[
\text{DISTANCE TRAVELLED} = \text{[ ]} \text{ (D)}
\]

\[
\text{W X D} = \text{[........]} \times \text{[. ........]} = \text{[............]} \text{ m}^2 \text{ (B)}
\]

\[
\text{APPLICATION RATE} = \frac{A}{B} \times 10000 \text{ (C)}
\]

\[
\text{[ ]} \div \text{[ ]} \times 10000 = \text{[ ]} \text{ L/ha}
\]

-------------------------------------------------------------------------------------------------------------------------------

AMOUNT OF CHEMICAL TO ADD TO THE TANK.

\[
\text{SPRAY TANK SIZE} = \text{[ ]} \text{ Litres}
\]

\[
\text{APPLICATION RATE} = \text{[ ]} \text{ L/ha (Above Answer)}
\]

\[
\text{CHEMICAL RATE} = \text{[ ]} \text{ L/ha (Label Rate)}
\]

\[
\text{TANK SIZE ÷ APPLICATION RATE x CHEMICAL RATE} \text{ (D)}
\]

\[
\text{[ ]} \div \text{[ ]} \times \text{[ ]} = \text{[ ]} \text{ L}
\]
5.2 Hand-held sprayer calibration

**Calibration checklist for hand-held equipment**

- Ensure the sprayer is clean and filled with the required volume of water for the exercise.
- Check and record the operating parameters (e.g. nozzle type, travel speed and height, product rate and water rate).
- Adjust the pressure setting to the required operating pressure or fit a spray management valve (SMV). Record the pressure.
- Check the equipment for possible leaks and blockages.
- Use a measuring cylinder or jug and collect the output from the nozzle(s) when the sprayer is operating at the required pressure for one minute. For high pressure nozzles, it may be easier to place a small length of hose (e.g. 1 m) over the nozzle.
- Record the volume collected for each nozzle.
- Measure the nozzle output(s) for one minute and record the result two more times.
- Work out the average output per minute for each nozzle from the three trials.
- Check that all nozzles are not more than 10% above the manufacturer’s new nozzle specifications. If they are more than 10% above, replace them. If they are below, this indicates there is probably a blockage in the nozzle or the filters.
- Record the total output from all of the nozzles measured and record the result at A on the calibration sheet.
- Record the swath width of the sprayer. When spraying beds with a hand-held nozzle the swath width may be taken as the bed width.
- Measure the distance travelled in one minute. This distance should be measured while moving the nozzle in the desired fashion to achieve uniform coverage of the bed.
- Calculate the area and record the result at B on the calibration sheet.
- Calculate and record the sprayer’s application rate at C on the calibration sheet.
- Record the label application rate.
- Record the spray tank volume.
- Calculate and record the amount of chemical required per spray tank volume. Record the result at D on the calibration sheet.

5.3 Boom sprayer calibration

**Check list for boom sprayer calibration**

- Ensure the sprayer is clean and filled with the required volume of water for the exercise.
- Adjust the PTO revs and pressure setting to the required operating pressure.
- Check and record the operating parameters such as nozzle type, operating speed (gear, engine revs and PTO revs), boom height, product rate and water rate).
- Check the equipment for possible leaks and blockages.
- Use a measuring cylinder or jug and collect the output from each of the nozzles when the sprayer is operating at the required pressure for one minute.
- Record the volume collected for each nozzle.
- Measure the nozzle outputs for one minute and record the result two more times.
- Work out the average output per minute for each nozzle from the three trials.
- Check that all nozzles are not more than 10% above the manufacturer’s new nozzle specifications. If they are more than 10% above, replace them. If they are below, this indicates there is probably a blockage in the nozzle or the filters.
- Record the total output from all of the nozzles measured and record the result at A on the calibration sheet.
- Record the swath width of the sprayer. When spraying beds with a hand-held nozzle the swath width may be taken as the bed width.
- Measure the distance travelled in one minute. This distance should be measured while moving the nozzle in the desired fashion to achieve uniform coverage of the bed.
- Calculate the area and record the result at B on the calibration sheet.
- Calculate and record the sprayer’s application rate at C on the calibration sheet.
- Record the label application rate.
- Record the spray tank volume.
- Calculate and record the amount of chemical required per spray tank volume. Record the result at D on the calibration sheet.
5.4 Calibration of misters (+ CDA)

Check list for mister calibration (+ CDA equipment)

- Ensure the sprayer is clean and the tank is filled with the required volume of water for the exercise.
- Check and record the operating parameters e.g. engine (head rotation speed), travel speed and height, product rate and water rate.
- Adjust the engine speed (or the head rotation) setting to that required for operating.
- Check the equipment for possible leaks and blockages.
- Detach the spray liquid feed from the reservoir at a point before it enters the nozzle (CDA head). Use a measuring cylinder or jug to collect the output from the pipe when the sprayer is operating at the required speed for one minute.
- Record the volume collected for each feed pipe (on large misters and CDA machinery there may be several).
- Measure the feed pipe output(s) for one minute and record the result two more times.
- Work out the average output per minute for each nozzle from the three trials. Then work out a total output for the equipment when all are functioning together. Enter this as A on the calibration sheet.
- Record the swath width of the sprayer. In this case, swath width is the maximum horizontal distance spray travels while still achieving effective coverage of the target. This can be determined accurately with the use of water sensitive paper placed on the target during a water test spray to check the number and size of droplets travelling to the target. Water sensitive paper and information on using it should be available from major pesticide suppliers.
- Measure the distance travelled in one minute by the equipment. This distance should be measured while moving the nozzle in the desired fashion to achieve uniform coverage of the bed.
- Enter the swath width and distance travelled then calculate the area and record at B on the calibration sheet.
- Calculate and record the sprayers application rate at C on the calibration sheet.
- Record the label application rate.
- Record the spray tank volume.
- Calculate and record the amount of chemical required per spray tank volume at D on the calibration sheet.
CHAPTER 6.
CASE STUDIES

The following section contains short case studies. These provide real examples of the current practices from the nursery industry in relation to purchase, storage and handling of agricultural pesticides. For each of the areas in which information was gathered, a rating has been used to indicate the level of performance relative to best practice for the nursery industry. Critical comments have also been provided for each case study to assist in understanding the development of best practice.

Key to the ratings used in the industry case studies contained in this section

<table>
<thead>
<tr>
<th>RATINGS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Must be improved</td>
<td>★</td>
</tr>
<tr>
<td>Could be improved</td>
<td>★ ★</td>
</tr>
<tr>
<td>Reasonable practice</td>
<td>★ ★ ★</td>
</tr>
<tr>
<td>Towards best practice</td>
<td>★ ★ ★ ★</td>
</tr>
</tbody>
</table>
### Case Study 1

**Production description:** Main products include ornamentals (gingers and heliconias, natives, gardenias, murrays, durantas, allamandas, cordylines, crotons). Produced in shade houses, igloo and open areas.

**Operation type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
</table>
| 1. Application equipment & techniques | Sprayer types: Hand pump sprayers for spot application.  
Calibration: Information not supplied. | ★★★ |
| 2. Chemical handling, storage & disposal | Transport: Ute.  
Storage: Locked refrigerator cabinet. | ★★★ |
|  | Personal protective equipment: For insecticides and all mixing operations a washable hat, overalls, boots, gloves and respirator are used. For herbicides and fungicides a washable hat, overalls and boots are used. | ★★★ |
|  | Disposal: Use remaining product on other produce (not usually an issue). | ★★★ |
|  | Typical spraying conditions:  
Wind speed: nil–5 km/hr.  
Temperature: less than 32°C.  
Humidity: Information not supplied. | ★★ |
|  | Spray drift management strategies: No strategies in place. | ★ |
|  | Record keeping: Information not supplied. | ★ |
|  | Emergency procedures: Information not supplied. | ★ |

### CRITICAL COMMENTS (by management area)

1. Calibration of equipment essential and records of calibration and usage must be kept.
2. Chemical handling  
i) Use of an old refrigerator cabinet is not recommended and it has no ventilation.  
ii) Eye protection, goggles or faceshield should be worn particularly when measuring or mixing concentrates.
3. Records must be kept of all pesticide use and application methods and conditions.
4. Training of staff is required, as are records, and emergency procedures for managing spills must be in place.
### Case Study 2

**Production description:** Main produce includes gardenias, lavenders and herbs. Open areas used for production only. Glasshouse used for propagation.

**Operation type:** Production nursery only.

### OVERALL RATING

☆☆

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Application equipment &amp; techniques</td>
<td><strong>Sprayer types:</strong> High volume PTO sprayer with hand gun, Silvan 400 L. Calibration: Variable cone nozzle on hydraulic hand gun.</td>
<td>☆☆☆</td>
</tr>
<tr>
<td></td>
<td><strong>Transport:</strong> Van.</td>
<td>☆</td>
</tr>
<tr>
<td></td>
<td><strong>Storage:</strong> In chemical store (no details given).</td>
<td>☆☆☆</td>
</tr>
<tr>
<td>2. Chemical handling, storage &amp; disposal</td>
<td><strong>Personal protective equipment:</strong> Washable hat, overalls, boots, gloves, goggles/face shield and respirator are used for insecticides (Bugmaster®, Malathion, Rogor), herbicides (Roundup®, Gesatop®, Tryquat®), fungicides (Kocide®, Bravo®, Octave®) and mixing operations.</td>
<td>☆☆☆</td>
</tr>
<tr>
<td></td>
<td><strong>Disposal:</strong> Only mix enough product for job requirements.</td>
<td>☆☆☆☆</td>
</tr>
<tr>
<td>3. Spray drift</td>
<td><strong>General operating parameters:</strong> Information not supplied.</td>
<td>☆</td>
</tr>
<tr>
<td></td>
<td><strong>Typical spraying conditions:</strong> Wind speed: Not measured. Temperature: less than 28°C. Humidity: Not measured.</td>
<td>☆☆☆☆</td>
</tr>
<tr>
<td></td>
<td><strong>Spray drift management strategies:</strong> Drift is not an issue, therefore no strategies in place.</td>
<td>☆</td>
</tr>
<tr>
<td>4. Overall management of spraying operations</td>
<td><strong>Training:</strong> All operators trained with farm chemical user course and apprenticeships.</td>
<td>☆☆☆½</td>
</tr>
<tr>
<td></td>
<td><strong>Record keeping:</strong> Handwritten onto a spread sheet.</td>
<td>☆☆☆</td>
</tr>
<tr>
<td></td>
<td><strong>Emergency procedures:</strong> Dial 000, SDS on hand, atropine on site and Ipecac syrup.</td>
<td>☆☆☆</td>
</tr>
</tbody>
</table>

### CRITICAL COMMENTS (by management area)

1. Hydraulic pressure variable nozzle hand guns are difficult to calibrate and this usually results in uneven dosing of the target with pesticide and run-off to waste.
2. Products need to be separated from driver/passengers during transport and the chemical store locked and clearly placarded.
3. Operating parameters need to be measured and recorded. Spray drift is always an issue and must be carefully considered.
4. Having atropine and Ipecac syrup on site is not recommended as it should only be administered under medical supervision.
## Case Study 3

**Production description:** Main product lines include annual flowers, vegetables, seedlings and herbs. Produces in shade house, glasshouse and open areas.  
**Operation Type:** Production nursery only.  

### MANAGEMENT AREA  
**CURRENT OPERATION**  
**RATING**

1. **Application equipment & techniques**
   - **Sprayer types:** QuickSpray (2 x retractable reels (600L tank) and 2 x 1600 cc Kubotas (200 L tanks).  
   - **Make and model:** Quickspray® 9TBE600, Kubota BS100E® and B6100E.  
   - **Calibration:** Regular calibration and equipment maintenance.  
   - **OVERALL RATING:** ☆☆½

2. **Chemical handling, storage & disposal**
   - **Transport:** Tray truck.  
   - **Storage:** Chemical storage shed.  
   - **Personal protective equipment:** Tyvek suits, boots, gloves (nitrile), goggles/face shield and respirator are used for all insecticide, herbicide, fungicide and all mixing operations.  
   - **Disposal:** Use excess on other crops. Operators don’t mix large quantities, but prefer to go back and re-fill if more is required.  
   - **OVERALL RATING:** ☆☆☆½

3. **Spray drift**
   - **General operating parameters:** Information not supplied.  
   - **Typical spraying conditions:**  
     - **Wind speed:** less than 10 km/hr.  
     - **Temperature:** less than 26°C.  
     - **Humidity:** Not applicable.  
   - **Spray drift management strategies:** Not necessary due to our location. We never spray when windy and most crops are under cover.  
   - **OVERALL RATING:** ☆☆

4. **Overall management of spraying operations**
   - **Training:** All operators are trained in the farm chemical users course.  
   - **Record keeping:** Spray request form—date, operator/s, purpose of spray, crops to spray, litres required, locations, chemical, rate, amount, wetter, unit speed, unit (equipment), weather, hours. All details recorded.  
   - **Emergency procedures:** Emergency showers, sand bags, safety protocols and first-aid officer on site during all spray operations.  
   - **OVERALL RATING:** ☆☆☆½

### CRITICAL COMMENTS (by management area)

1. High volume hydraulic spraying can result in waste of pesticide and run-off to the environment.  
2. The pesticide storage area needs to be locked, well ventilated and placarded.  
3. Spray drift is always an issue requiring consideration and careful planning, even high volume hydraulic sprayers produce some fines (small droplets prone to drift).  
4. Emergency contact numbers and product SDS sheets need to be available.
### Case Study 4

**Production description:** Main product lines include house plants, exotic shrubs (gardenias and natives). Produces in shade house, glasshouse and open areas.  
**Operation type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Application equipment &amp; techniques</td>
<td>Sprayer types: Annovi Reverbi AR 30 pressure sprayer with 300 L tank, 2 hoses and reels with 2 turbo gun 400s. Granule applicator (supplied with product) and knapsack sprayer used for some herbicide operations.</td>
<td>★★★★★</td>
</tr>
<tr>
<td>2. Chemical handling, storage &amp; disposal</td>
<td>Transport: By suppliers vehicle – flat bed truck with secure chemical box bolted to tray.</td>
<td>★★★★★</td>
</tr>
<tr>
<td></td>
<td>Storage: Secure locked room, shelved, ventilated and signed.</td>
<td>★★★★★</td>
</tr>
<tr>
<td></td>
<td>Personal protective equipment: PPE used for spraying insecticides (Orthene Xtra®, Vertimec®, Pirimor Wg®, Confidor® 200 SC, Kelthane®, Talstar® 80 SC) and fungicides (Rovral® Aquaflo, Fosject®, Wettabel Sulphur, Bravo® 720) (including their related mixing operations) includes overalls with hood, boots, gloves and power helmet. Overalls with hood, boots, gloves and respirator are used for herbicide (Ronstar, Rout, Weedmaster) operations. The same equipment is used for mixing herbicides plus goggles/face shield.</td>
<td>★★★</td>
</tr>
<tr>
<td></td>
<td>Disposal: Extra pesticide is sprayed on other crops.</td>
<td>★★★½</td>
</tr>
<tr>
<td>3. Spray drift</td>
<td>General operating parameters: 2.75 L/min @ 10 bar</td>
<td>★★</td>
</tr>
<tr>
<td></td>
<td>Typical spraying conditions: Do not have facilities to measure conditions. Spraying ceases when considered to be ineffective or to produce too much drift.</td>
<td>★</td>
</tr>
<tr>
<td></td>
<td>Spray drift management strategies: Do not spray when wind is too strong or blowing from particular direction.</td>
<td>★☆</td>
</tr>
<tr>
<td>4. Overall management of spraying operations</td>
<td>Training: All spray operators are ChemCert accredited.</td>
<td>★★★★★</td>
</tr>
<tr>
<td></td>
<td>Record keeping: Will use computer records in future. Presently use record sheets (weather conditions, PPE, name of mix, trade name, quantity, vat volume, area to be sprayed, plants to be sprayed, plant code, size, signature).</td>
<td>★★★</td>
</tr>
<tr>
<td></td>
<td>Emergency procedures: Office is always open when any spray application occurs. Spill kits are supplied to contain any spills, safety showers on site.</td>
<td>★☆☆</td>
</tr>
</tbody>
</table>

**CRITICAL COMMENTS (by management area)**

1. Calibration information for all sprayers is required and calibration needs to be repeated regularly.  
2. Records of respirator cartridge usage need to be kept. Respirators and all other PPE should be carefully stored away from pesticides.  
3. Environmental conditions before and during spraying should be measured. A pressure of 10 bar will produce a lot of small droplets, which may drift out of the target area.  
4. Emergency numbers and SDS information for products should be available.
## Case Study 5

**Production description:** Indoor plants. Produces in shadehouses.  
**Operation type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
</table>
| **1. Application equipment & techniques** | Sprayer types: Optima Croplands  
**Make and model:** Silvan 300 L tank. Pump and motor (HR30TG) 5½ Honda motor.  
**Calibration:** Output of machinery 6 L every 46 seconds. | ★★ |
| **2. Chemical handling, storage & disposal** | Transport: Delivery truck.  
**Storage:** In a chemical shed.  
**Personal protective equipment:** For insecticide (Vertimec®) and fungicide (copper, Dithane®, sulfur) operations a washable hat, overalls, boots, gloves, sunglasses and respirator are used. For herbicide operations (Roundup®) overalls, boots, gloves and respirator are used. Overalls, boots, gloves, face shield, respirator and apron are used for mixing operations.  
**Disposal:** Respray over the crop or target area. | ★★½ |
| **3. Spray drift** | **General operating parameters:** Information not supplied.  
**Typical spraying conditions:**  
Wind speed: less than 30 km/h.  
Temperature: less than 32°C.  
Humidity: 65% or higher. | ★ ★★★ |
| **Spray drift management strategies:** Fibre glass walls and trees. | ★★½ |
| **4. Overall management of spraying operations** | **Training:** All operators have been trained through ChemCert.  
**Record keeping:** Record keeping sheets (date, crop type, pest or problem, area treated, amount of mix used, notes, results, name of operator, signature).  
**Emergency procedures:** Bucket, shovel, plastic bags and broom are all kept for spills. Shower is close by. | ★★★★ |

### CRITICAL COMMENTS (by management area)

1. Spraying equipment needs to be calibrated and records kept.  
2. The pesticide storage area needs to be well ventilated, locked and well placarded.  
3. Operating conditions, including equipment settings need to be recorded for all operations.
Case Study 6

**Production description:** Outdoor trees, shrubs and groundcovers. Produces in shadehouse and open areas.
**Operation type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Application equipment &amp; techniques</td>
<td><strong>Sprayer types:</strong> Hydraulic spray pump, PTO-driven, Hardi mistblower®. <strong>Calibration:</strong> Information not supplied.</td>
<td>✴✴✴✴</td>
</tr>
<tr>
<td>2. Chemical handling, storage &amp; disposal</td>
<td><strong>Transport:</strong> Delivered by supplier. <strong>Storage:</strong> Chemical shed. <strong>Personal protective equipment:</strong> Overalls, boots, gloves, goggles/face shield and respirator used for all insecticide, herbicide and fungicide applications. <strong>Disposal:</strong> Extra product used on stock gardens.</td>
<td>✴✴✴✴✴</td>
</tr>
<tr>
<td>3. Spray drift</td>
<td><strong>General operating parameters:</strong> Information not supplied. <strong>Typical spraying conditions:</strong> Wind speed: When leaves are blowing across ground. And when spray may drift towards sensitive areas. Temperature: Done early morning. Humidity: N/A</td>
<td>✴ ✴</td>
</tr>
<tr>
<td>4. Overall management of spraying operations</td>
<td><strong>Training:</strong> All operators have been ChemCert accredited. <strong>Record keeping:</strong> New industry spray diary. <strong>Emergency procedures:</strong> SDS sheets available, emergency shower.</td>
<td>✴✴✴✴✴</td>
</tr>
</tbody>
</table>

**CRITICAL COMMENTS (by management area)**
1. The term 'mistblower' is confusing, it might refer to an air shear sprayer or an air assisted hydraulic sprayer (most likely the second).
2. The storage area for pesticides needs to be locked and well ventilated.
3. Records must be kept of operating conditions and the calibration of equipment.
4. A spill kit is also required along with emergency contact numbers.
### Case Study 7

**Production description:** Main product lines include plant seedlings (vegetables, potted colour, specialised flowers, pot plants), herbs, tropical foliage plants, trees and shrubs. 70 acre orchard. Produces in shadehouse, glasshouse and open areas.  
**Operation type:** Production nursery only and retail.  

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Application equipment &amp; techniques</strong></td>
<td>Small pneumatic sprayers, knapsack for small use areas, 450 L spray carts from tractor, PTO-driven.</td>
<td>✭✭✭</td>
</tr>
</tbody>
</table>
**Make and model:** Mostly all Hardi equipment.  
**Calibration:** Information not supplied. | ✭ N/A |  
| **2. Chemical handling, storage & disposal** | Supplier's vehicle (truck or heavy ute). | ✭✭✭✭ |  
**Transport:** Supplier's vehicle (truck or heavy ute). | ✭✭✭✭ |  
**Storage:** Locked, brick shed, plus separate locked compartment for some chemicals. The shed is specially constructed for spillage and has concrete bunding. | ✭✭✭✭ |  
**Personal protective equipment:** For insecticide (Orthene, Pounce®), herbicide (Rout®, Gramoxone®), fungicide (Zineb®, Saprol®, Kocide®) and mixing (not insecticides) operations the PPE used includes washable hat, disposable overalls, boots, gloves, goggles and respirator. The same is used for Roundup® and mixing insecticides minus the washable hat, and potentially no goggles for the Roundup®. | ✭✭✭✭½ |  
**Disposal:** Excess spray is sometimes dispersed over grassed wasteland away from drains, creeks etc. or collected in a sump from rinsing operations. | ✭✭✭ |  
| **3. Spray drift** | Ceramic nozzles, at 100 psi (5 L/min). | ✭✭ |  
**General operating parameters:** Ceramic nozzles, at 100 psi (5 L/min). | ✭✭ |  
**Typical spraying conditions:** Wind speed: By observation. Weather station phoned daily.  
Temperature: less than 27°C if possible.  
Humidity: Difficult in houses, but good drying day essential. When chemical can't dry, we won't spray. We phone for dew point if in doubt. | ✭✭✭½ |  
**Spray drift management strategies:** Shadehouses have sidewalls mostly. Vegetation screens are planted for open areas. | ✭✭✭ |  
| **4. Overall management of spraying operations** | All spray operators are ChemCert accredited. | ✭✭✭✭ |  
**Training:** All spray operators are ChemCert accredited. | ✭✭✭✭ |  
**Record keeping:** Record sheet (date, crops, chemical, rate/litre, reason, start & finish time, operators signature). | ✭✭✭ |  
**Emergency procedures:** Showers, eye wash and workplace health and safety officer on site. Spillage bucket, SDS and emergency contact numbers available.  
**Extra notes:** All personnel using pesticides have blood samples taken at the firm's expense annually by a visiting doctor. The list of chemicals used is forwarded to the doctor. No person to date has been found to be in any danger. | ✭✭✭ |  

### CRITICAL COMMENTS (by management area)

1. Calibration of all equipment is essential and records should be kept.  
2. The same PPE for all products is recommended as good practice to avoid confusion.  
3. A full record of operating conditions is necessary for all applications of pesticide.  
4. The overall management is very good.
**Case Study 8**

**Production description:** Main product lines include roses and topiary. Produces in shadehouse and open areas.  
**Operation type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
</table>
| 1. Application equipment & techniques | Sprayer types: Quickspray unit.  
Calibration: Information not supplied. | ★★★★ |
| 2. Chemical handling, storage & disposal | Transport: Delivered by company of purchase.  
Storage: In a steel locked shed. | ★★★★½ |
| | Personal protective equipment: Overalls, boots, gloves, goggles/face shield and respirators are used for insecticides (Confidor®, Lorsban®Talstar®), herbicides (Basta®, Rout®, Afalon®), fungicides (Dithane®, Ridomil®) for mixing and spraying operations. | ★★★★ |
| | Disposal: We don't have any, all our chemicals are always bought on demand. | Not assessable |
| 3. Spray drift | General operating parameters: No information given. | |
| | Typical spraying conditions:  
Wind speed: We have to judge wind speed.  
Temperature: Generally we do not spray above 30°C.  
Humidity: Not Applicable. | ★ |
| | Spray drift management strategies: No strategies as we do not spray when weather conditions are unsuitable. | ★½ |
| 4. Overall management of spraying operations | Training: All are either qualified or trained in the farm chemical users course. | ★★★ |
| | Record keeping: All records are kept in a book, for every spray application. | ★★★ |
| | Emergency procedures: We have a shower, fire extinguisher and emergency phone number. | ★★★½ |

**OVERALL RATING**  
★ ★½
Case Study 9

**Production description:** Main products include fuscias, hibiscus, hydrangeas, bougainvillea, Australian natives and outdoor shrubs. Produce in shadehouse, glasshouse (propagation only), open areas and igloo. Total area 2.3ha.

**Operation type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
</table>
| 1. Application equipment & techniques                | **Sprayer types:** High volume sprayer, AR 30 SP (Annovi Reverberi) pressure pump – powered by Kubota.  
**Calibration:** Information not supplied.          | ★★★    |
| 2. Chemical handling, storage & disposal             | **Transport:** Truck.  
**Storage:** Locked shed.                            | ★★★    |
|                                                        | **Personal protective equipment:** Disposable overalls, rubber boots, disposable gloves and respirator used for insecticide (Maverick®, Confidor®), herbicide (Glyphosate®, Spray Seed®, Ronstar®) and fungicide (Baycor 300®, Aliette®, Ridomil Gold®) operations. | ★★★★ ½ |
|                                                        | **Disposal:** Only mix required amount of chemical. Any excess is sprayed onto stock plants as a preventative. | ★★★★ ½ |
| 3. Spray drift                                       | **General operating parameters:** Information not supplied.                         |        |
|                                                        | **Typical spraying conditions:**  
Wind speed: Information not supplied.  
Temperature: Summer months early morning or evening.  
Humidity: Information not supplied. | ★        |
|                                                        | **Spray drift management strategies:** Information not supplied.                   | ★        |
| 4. Overall management of spraying operations         | **Training:** All spray operators participate in the industry training refresher every 2–3 years. | ★★★    |
|                                                        | **Record keeping:** Chemical record book (date, chemical used, rate & quantity mixed, plants sprayed, operator). | ★★★    |
|                                                        | **Emergency procedures:** No procedures.                                           | ★        |

**CRITICAL COMMENTS (by management area)**

1. Calibration of spraying equipment and the keeping of records are both essential.
2. A well-ventilated and signed pesticide storage area required. Transport truck needs to be adequately managed.
3. Measurement of operating conditions when spraying and keeping records is important.
4. Emergency procedures including contact numbers and an emergency spill kit need to be available.
### Case Study 10

**Production Description:** Product lines include semi-advanced and advanced plants, produced in open areas only.

**Operation Type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
</table>
| 1. Application equipment & techniques | **Sprayer types:** Contract sprayers using hand lances and boom sprayer. Also 4WD bike with CDA equipment.  
**Make and model:** Quickspray (400 Lt) 3-pt. linkage Silvan boom and 1200 Undavina CDA.  
**Calibration:** Information not supplied. | ★★½ ★ |
| 2. Chemical handling, storage & disposal | **Transport:** Chemical company delivers via trucks.  
**Storage:** Lockable cabinet in locked shed. | ★★★|
|  | **Personal protective equipment:** For all insecticide (Folimat 800, Mavrik®), herbicide (Roundup®, Gesatop 560®, Ronstar®) and fungicide (Bravo 720®, Baycor 300® and Copper Oxy) mixing operations overalls, boots, gloves, goggles/face shield and respirator or power helmet are used. | ★★★ |
|  | **Disposal:** Very rare to have remaining product. If necessary it is emptied onto grassy area near washdown site if not used up on another suspect crop, or (if herbicide) stored in drums in spray shed. | ★★ |
| 3. Spray drift | **General operating parameters:** Information not supplied.  
**Typical spraying conditions:**  
Wind speed: Information not supplied.  
Temperature: less than 30°C.  
Humidity: 50% or higher. | ★★½ |
|  | **Spray drift management strategies:** Boundary plantings and windbreaks. | ★★★ |
| 4. Overall management of spraying operations | **Training:** Some operators have been trained in the Farm chemical users course. | ★★ |
|  | **Record keeping:** Spray record sheet (date, area ref., crop, weed/pest/disease targeted, chemicals & additives used, recommended rate, litres of spray applied, temperature, signature). | ★★½ |
|  | **Emergency procedures:** SDS sheets easily accessible, colour tags to be worn when spraying eg. if S6 – yellow tag. Up to date first aid cabinet – IPECAC and atropine tablets, long life milk. Trained first aiders on site. | ★★★ |

### CRITICAL COMMENTS (by management area)

1. Calibration of spraying equipment needs to be carried out regularly and records kept. Contractors should be asked to supply records of their activities.
2. The pesticide storage cabinet should be well ventilated and signed.
3. Operating conditions during spraying should be measured and recorded.
4. All operators should be ChemCert accredited. Ipecac syrup and atropine should not be available as they can only be used under direct medical supervision.
## Case Study 11

**Production description:** Main product lines include annuals and vegetables. Specialises in one species of flowering plant. Produces in shadehouse, glasshouse and open areas.

**Operation Type:** Production nursery only.

<table>
<thead>
<tr>
<th>MANAGEMENT AREA</th>
<th>CURRENT OPERATION</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Application equipment &amp; techniques</td>
<td><strong>Sprayer Types:</strong> 200 L spray machine Hardi pump. Also 8/t Hozelock handspray used at times (for glasshouse and open areas only). <strong>Calibration:</strong> Information not supplied.</td>
<td>★★½</td>
</tr>
<tr>
<td>2. Chemical handling, storage &amp; disposal</td>
<td><strong>Transport:</strong> Ute.</td>
<td>★★</td>
</tr>
<tr>
<td></td>
<td><strong>Storage:</strong> In certified storage which complies with American and Australian Standards.</td>
<td>★★★</td>
</tr>
<tr>
<td></td>
<td><strong>Personal protective equipment:</strong> Overalls, boots, gloves and respirators are used for insecticide (Ambush®, Mavrik®, Pirimor®), herbicide (Roundup®, Gesatop®) and fungicide (Dithane®) operations. Mixing information not included.</td>
<td>★★½</td>
</tr>
<tr>
<td></td>
<td><strong>Disposal:</strong> Excess is shared between growers or disposed of in a separate chemical drainage system.</td>
<td>★</td>
</tr>
<tr>
<td>3. Spray drift</td>
<td><strong>General operating parameters:</strong> Information not supplied.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Typical spraying conditions:</strong>&lt;br&gt;Wind speed: Moderate.&lt;br&gt;Temperature: less than 30°C.&lt;br&gt;Humidity: Humidity in Melbourne not an issue.</td>
<td>★½</td>
</tr>
<tr>
<td></td>
<td><strong>Spray drift management strategies:</strong> All staff are notified of spraying to vacate area. No Entry signage erected.</td>
<td>★★</td>
</tr>
<tr>
<td>4. Overall management of spraying operations</td>
<td><strong>Training:</strong> All operators are trained in the farm chemical users course or in the house training manual.</td>
<td>★★★</td>
</tr>
<tr>
<td></td>
<td><strong>Record keeping:</strong> Record sheets include spray list, chemicals used, chemical manifest, water treatment, drenching sheet.</td>
<td>★★★</td>
</tr>
<tr>
<td></td>
<td><strong>Emergency procedures:</strong> No information supplied.</td>
<td>★</td>
</tr>
</tbody>
</table>

### CRITICAL COMMENTS (by management area)

1. Calibration of all pesticide application equipment is essential and records must be kept.
2. Disposal: It is not advisable to store pesticide mixtures; mixing can be the most hazardous time when using pesticides and mixing and use protocols need to be in place.
3. Environmental conditions at the time of pesticide application must be measured and recorded.
4. Emergency numbers and a spill kit need to be available.
REFERENCES AND FURTHER READING


APPENDIX 1. CONTACT DETAILS

DISPOSAL OF USED PESTICIDE CONTAINERS AND CHEMICALS

drum MUSTER
Phone: 1800 008 707
Website: www.drummuster.com.au
ChemClear
Phone: 1800 008 707
Website: www.chemclear.com.au

LEGISLATION
Australasian Legal Information Institute
Website: www.austlii.edu.au
ComLaw
Website: www.comlaw.gov.au

New South Wales
Nursery & Garden Industry, NSW and ACT (NGINA)
344–348 Annangrove Road
Rouse Hill, NSW 2155
Phone: 02 9679 1472 Fax: 02 9679 1655
Email: info@ngina.com.au
Website: www.ngina.com.au
Environmental Protection Agency (EPA)
Website: http://www.epa.nsw.gov.au/pesticides/index.htm
New South Wales legislation
Website: www.legislation.nsw.gov.au

Northern Territory
Nursery & Garden Industry, Northern Territory (NGINT)
PO Box 348
Palmerston, NT 0831
Phone: 08 8983 3233 Fax: 08 8983 3244
Email: ngint@ntha.com.au
Department of Primary Industries and Fisheries
Phone: 08 8999 5511
(Ask for Chemical Services)
Website: www.nt.gov.au/
Northern Territory legislation
Website: www.dcm.nt.gov.au

Queensland
Nursery & Garden Industry, Queensland (NGIQ)
Cnr Orange Grove & Riawena Roads
PO Box 345, Salisbury, QLD 4107
Phone: 07 3277 7900 Fax: 07 3277 7109
Email: info@ngiq.asn.au
Website: www.ngiq.asn.au
Department of Agriculture, Fisheries and Forestry Call Centre
Phone: 13 25 23 (ask to speak to the appropriate policy officer within the DAFF Animal and Plant Health Service)
Website: www.daff.qld.gov.au
Queensland legislation

South Australia
Nursery & Garden Industry, South Australia (NGISA)
505 Fullarton Road
Netherby, SA 5062
Ph: +61 8 8372 6822 Phone: 08 8271 1012
Fax: 08 8372 6833
Email: gfuller@ngisa.com.au
Website: www.ngisa.com.au
Biossecurity South Australia
Website: www.pir.sa.gov.au/biosecuritysa/ruralchem
South Australia legislation
Website: www.legislation.sa.gov.au

Tasmania
Department of Primary Industries, Parks, Water and Environment
Phone: 1300 368 550
Spray drift complaints: 1800 005 244
Nursery & Garden Industry, Tasmania
9 Takari Place
Mornington TAS 7018
PO Box 3009
Rosny Park TAS 7018
Phone: 03 6244 7977  Fax: 03 6244 7977
Email: ngit@bigpond.com
Tasmanian legislation
Website: www.thelaw.tas.gov.au

Victoria
Nursery Industry Association of Victoria (NGIV)
3/307 Wattletree Road
Malvern East VIC 3145
PO Box 2280, Wattletree Road LPO,
East Malvern VIC 3145
Phone: 03 9576 0599  Fax: 03 9576 0431
Email: ngiv@ngiv.com.au
Website: www.ngiv.com.au
Department of Environment and Primary Industries
Phone: 13 16 86
chemical-use
Victorian legislation
Website: www.legislation.vic.gov.au

Western Australia
Nursery & Garden Industry, Western Australia (NGIWA)
PO Box 135
Mount Helena WA 6082
Phone: 0419 930 008
Email: reception@ngiwa.com.au
Department of Agriculture and Food
Phone: 08 9368 3333
Website: www.agric.wa.gov.au/PC_92826.html
Western Australian legislation

PRODUCTS AND SERVICES
Nursery & Garden Industry Australia (NGIA)
Unit 58 Quantum Corporate Park
5 Gladstone Road
Castle Hill, NSW 2154
PO Box 7129
Baulkham Hills BC, NSW 2153
Phone: 02 8861 5100  Fax: 02 9659 3446
Email: info@ngia.com.au

Website: www.ngia.com.au For information on FMS,
EcoHort, NIASA and BioSecure HACCP.
Agsafe Limited
Level 2, AMP Tower, 1 Hobart Place, Canberra City,
ACT 2601
GPO Box 816, Canberra City, ACT 2601
Phone: 02 6230 4799  Fax: 02 6230 6710
Email: info@agsafe.com.au
Website: www.agsafe.com.au
ChemCert Australia Inc.
For all enrolment and courses inquiries:
Freecall: 1800 444 228
Website: www.chemcert.com.au
Cornell University Pesticide Active Ingredient information
Website: pmep.cce.cornell.edu/profiles/index.html
Extonet Pesticide Information Profiles
Website: extoxnet.orst.edu/pips/qhindex.html
Standards Australia
Level 10, The Exchange Centre
20 Bridge Street, Sydney
GPO Box 476
Sydney, NSW 2001
Freecall within Australia: 1800 035 822
Fax: 02 9237 6010
Website: www.standards.org.au
Standards Australia Publications Distributor - SAI Global
Office hours: 8 am to 5 pm (AEST/AEDT)
Call within Australia: 131 242
Faxes within Australia: 1300 65 49 49
Email: sales@saiglobal.com
Web shop: http://infostore.saiglobal.com/store/
Poisons information hotline
Phone: 13 11 26
Australian Pesticides and Veterinary Medicines Authority
(APVMA)
The APVMA is the regulator of pesticides and
veterinary medicines up until the point of retail sale.
For regulation policy issues, chemical use issues or for
the regulation of other chemical products, please view
information from the responsible organisations.
18 Wormald Street, Symonston, ACT, 2609, Australia
PO Box 6182, Kingston, ACT, 2604, Australia
Phone: +61 2 6210 4701
Adverse experiences
To report an unintended effect from the use of registered agricultural or veterinary chemicals.
FreeCall: 1800 700 583 (within Australia). Charges apply for calls made from mobile phones
Fax: +61 2 6210 4776
Email: aerp@apvma.gov.au

Agricultural chemical products, active constituents and permits
Phone: +61 2 6210 4748 Fax: +61 2 6210 4776
Email: pesticides@apvma.gov.au

Fees, Levies and Invoice queries
Phone: +61 2 6210 4852 Fax: +61 2 6210 4874
Email: finance@apvma.gov.au

Feedback and complaints
Phone: +61 2 6210 4746 Fax: +61 2 6210 4776
Email: feedback@apvma.gov.au
# Appendix 2. Glossary of Pesticide Terms

## Common Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APVMA</td>
<td>Australian Pesticides and Veterinary Medicines Authority</td>
</tr>
<tr>
<td>EC</td>
<td>Emulsifiable concentrate—a liquid pesticide formulation</td>
</tr>
<tr>
<td>IPM</td>
<td>Integrated pest management</td>
</tr>
<tr>
<td>MRL</td>
<td>Maximum residue level</td>
</tr>
<tr>
<td>MSDS</td>
<td>Material safety data sheet (now known as SDS, see below)</td>
</tr>
<tr>
<td>OC</td>
<td>Organochlorine pesticide</td>
</tr>
<tr>
<td>OP</td>
<td>Organophosphate pesticide</td>
</tr>
<tr>
<td>SC</td>
<td>Suspended concentrate—a liquid pesticide formulation</td>
</tr>
<tr>
<td>SDS</td>
<td>Safety data sheet</td>
</tr>
<tr>
<td>SP</td>
<td>Soluble powder pesticide formulation</td>
</tr>
<tr>
<td>SP</td>
<td>Synthetic pyrethroid pesticide</td>
</tr>
<tr>
<td>ULV</td>
<td>Ultra low volume sprays, usually oil based</td>
</tr>
</tbody>
</table>

## Defined Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>A volatile solvent, such as that used in many nail polish removers.</td>
</tr>
<tr>
<td>Acidic</td>
<td>A low pH (&lt; 7) e.g. vinegar is mildly acidic, sulphuric acid is very acidic.</td>
</tr>
<tr>
<td>Active constituent</td>
<td>That part of a farm chemical formulation that is biologically active on the pest target.</td>
</tr>
<tr>
<td>Adjuvant</td>
<td>A secondary ‘helper’ chemical added to improve the effectiveness of a pesticide spray.</td>
</tr>
<tr>
<td>Aerosol</td>
<td>Fine droplets, small enough to stay suspended in air.</td>
</tr>
<tr>
<td>Alkaline</td>
<td>A high pH (&gt; 7) e.g. bore water is mildly alkaline, sodium hydroxide is very alkaline.</td>
</tr>
<tr>
<td>Anionic</td>
<td>Negatively charged (ions).</td>
</tr>
<tr>
<td>Anti-foaming agent</td>
<td>A substance added to a formulation to prevent excessive foam forming during the mixing of ingredients.</td>
</tr>
<tr>
<td>Buffering agent</td>
<td>A chemical which, when added to a solution, has the ability to resist changes to pH or hydrogen ion concentrations. Acidifying buffers are used to counter alkaline bore water supplies that can improve spray solution stability and performance.</td>
</tr>
<tr>
<td>Cationic</td>
<td>Positively charged (ions).</td>
</tr>
<tr>
<td>Diffusion</td>
<td>The spreading and penetration of particles by natural movement into space that may be enclosed, as in the case of respirator filter elements.</td>
</tr>
<tr>
<td>Dispersal</td>
<td>The process of spreading a population, usually by seeds or spores.</td>
</tr>
<tr>
<td>Efficacy</td>
<td>A measure of how well a product does the job it was designed to do.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Emulsifiable concentrate</strong></td>
<td>A chemical formulation consisting of an active constituent dissolved in an organic solvent together with an emulsifier to facilitate the formation of an even, milky emulsion when mixed with water.</td>
</tr>
<tr>
<td><strong>Flowable concentrate</strong></td>
<td>Sometimes called suspension concentrates. These are suspensions of finely milled solid active particles mixed with and suspended, usually, in water that can be measured out by liquid volume.</td>
</tr>
<tr>
<td><strong>Formulation</strong></td>
<td>The make-up of the farm chemical as purchased. It consists of the active constituent(s) together with a number of other components that are added to assist handling, efficacy, safety and stability.</td>
</tr>
<tr>
<td><strong>Hydrolysis</strong></td>
<td>The breakdown of the active ingredient over time, when mixed in poor quality water.</td>
</tr>
<tr>
<td><strong>Integrated pest management</strong></td>
<td>The coordinated use of all available pest management methods to keep pest populations below economic injury levels.</td>
</tr>
<tr>
<td><strong>Larva</strong></td>
<td>An immature or young insect that has a pupal or resting stage.</td>
</tr>
<tr>
<td><strong>Lifecycle</strong></td>
<td>The successive life stages of a plant or animal as they progress from birth to death.</td>
</tr>
<tr>
<td><strong>Maximum residue limit</strong></td>
<td>The maximum legal amount of chemical residue expressed in parts per million that is permitted to be present in marketed produce. No chemical is given clearance for use on a crop or animal unless an MRL has previously been established.</td>
</tr>
<tr>
<td><strong>Mode of action</strong></td>
<td>How the agrochemical actually works, e.g. nerve poison.</td>
</tr>
<tr>
<td><strong>Non-ionic</strong></td>
<td>A molecule that does not ionise when placed in water. Nearly all wetting agents used in agriculture are non-ionic.</td>
</tr>
<tr>
<td><strong>Nymph</strong></td>
<td>An immature insect that does not have a pupal or resting stage, e.g. green vegetable bug.</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>A measure of acidity. Low pH is acidic (&lt; 7), high pH is alkaline (&gt; 7).</td>
</tr>
<tr>
<td><strong>Phytotoxic</strong></td>
<td>A damage response to applying agrochemical, such as a chemical burn.</td>
</tr>
<tr>
<td><strong>Resistance</strong></td>
<td>The appearance of a high level of tolerance to a pesticide in a pest species. This is likely to occur when the pest population has been subject to high selection pressure by repeated exposure to pesticides with a similar mode of action.</td>
</tr>
<tr>
<td><strong>Selective chemicals</strong></td>
<td>Pesticides that have the ability to selectively target a pest without affecting the crop in which the pest is present.</td>
</tr>
<tr>
<td><strong>Sequestering agent</strong></td>
<td>In formulations, adjuvants designed to differentially combine with certain metallic elements, isolate them in soluble compounds and prevent the precipitation of solid particles that could block filters and nozzles.</td>
</tr>
<tr>
<td><strong>Soluble powder</strong></td>
<td>A chemical formulation that is packaged as a powder and dissolves completely in water to form a spray solution.</td>
</tr>
<tr>
<td><strong>Stable/stability</strong></td>
<td>Meteorological conditions when little or no wind occurs. Not suitable for spraying.</td>
</tr>
<tr>
<td><strong>Stickers</strong></td>
<td>An adjuvant added to a product to reduce run-off.</td>
</tr>
<tr>
<td><strong>Solution</strong></td>
<td>A liquid containing one or more compounds in a completely homogenous state. Usually refers to chemicals dissolved in and mixed with water (i.e. an aqueous solution).</td>
</tr>
<tr>
<td><strong>Surfactant</strong></td>
<td>Short for ‘surface active agent’. This term is used to describe wetting agents, stickers and spreaders. Usually non-ionic when used with farm chemicals.</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Suspension concentrate</strong></td>
<td>See ‘flowable concentrate’.</td>
</tr>
<tr>
<td><strong>Synergist</strong></td>
<td>A chemical that increases the biological effect of another when the two are mixed.</td>
</tr>
<tr>
<td><strong>Synthetic pyrethroids, organophosphates and carbamates</strong></td>
<td>Insecticides that act as a nerve poison. They work the same way on humans as they do on insects.</td>
</tr>
<tr>
<td><strong>Target</strong></td>
<td>The place where the spray should be directed, which depends on how the product actually works (i.e. its mode of action).</td>
</tr>
<tr>
<td><strong>Translocated herbicides</strong></td>
<td>Once applied, these products will move within the plant to the site of action.</td>
</tr>
<tr>
<td><strong>Water miscible</strong></td>
<td>Another liquid that is able to mix completely with water to form a homogenous mixture.</td>
</tr>
<tr>
<td><strong>Wettable powder</strong></td>
<td>A chemical formulation designed to form a suspension when mixed with water to make up a pesticide spray solution.</td>
</tr>
<tr>
<td><strong>Wetter</strong></td>
<td>See ‘surfactant’.</td>
</tr>
</tbody>
</table>
APPENDIX 3. PESTICIDE ACTIVITY GROUPS AND STRATEGIES TO AVOID PESTICIDE RESISTANCE

The following pages are a list of the major groups of pesticide chemicals published by APVMA. These are grouped by target into insecticides, fungicides and herbicides, and each is described in terms of its activity on the target organism, usually the disruption of a metabolic pathway. Also included is a description of management strategies to avoid pests developing resistance to pesticides and practical examples from the nursery industry.


### Resistance management groups: Insecticides

**Table 8. Avcare Insecticide Resistance Action Committee (AIRAC) Mode of Action Classification for Insecticides**

<table>
<thead>
<tr>
<th>Group</th>
<th>Primary Target Site</th>
<th>Chemical Subgroups</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Acetyl choline esterase inhibitors</td>
<td>carbamates*</td>
</tr>
<tr>
<td></td>
<td>* all members of this class may not be cross resistant</td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td></td>
<td>organophosphates*</td>
</tr>
<tr>
<td>2A</td>
<td>GABA-gated chloride channel antagonists</td>
<td>cyclodienes</td>
</tr>
<tr>
<td>2B</td>
<td></td>
<td>polychlorocycloalthanes</td>
</tr>
<tr>
<td>2C</td>
<td></td>
<td>fiproles</td>
</tr>
<tr>
<td>3A</td>
<td>Sodium channel modulators</td>
<td>pyrethroids and pyrethrins</td>
</tr>
<tr>
<td>4A</td>
<td>Acetyl choline receptor agonists/antagonists</td>
<td>chloronicotinyls</td>
</tr>
<tr>
<td>4B</td>
<td></td>
<td>nicotine</td>
</tr>
<tr>
<td>4C</td>
<td></td>
<td>cartap, bensultap</td>
</tr>
<tr>
<td>5A</td>
<td>Acetyl choline receptor modulators</td>
<td>spinosyns</td>
</tr>
<tr>
<td>6A</td>
<td>Chloride channel activators</td>
<td>avermectin, emamectin benzoate</td>
</tr>
<tr>
<td>6B</td>
<td></td>
<td>milbemycin</td>
</tr>
<tr>
<td>7A</td>
<td>Juvenile hormone mimics</td>
<td>methoprene, hydroprene</td>
</tr>
<tr>
<td>7B</td>
<td></td>
<td>fenoxy carb</td>
</tr>
<tr>
<td>7C</td>
<td></td>
<td>pyriproxifen</td>
</tr>
<tr>
<td>8A</td>
<td>Compounds of unknown or non specific mode of action (fumigants)</td>
<td>methyl bromide</td>
</tr>
<tr>
<td>8B</td>
<td></td>
<td>phosphine generating compounds</td>
</tr>
<tr>
<td>9A</td>
<td>Compounds of unknown or non specific mode of action (selective feeding blockers)</td>
<td>pymetrozine</td>
</tr>
<tr>
<td>9B</td>
<td></td>
<td>cryolite</td>
</tr>
<tr>
<td>10A</td>
<td>Compounds of unknown or non specific mode of action (mite growth inhibitors)</td>
<td>clofentezine, hexythiazox</td>
</tr>
<tr>
<td>11A</td>
<td>Microbial disrupters of insect midgut membranes (includes Transgenic B.t. crops) * all members of this class may not be cross resistant</td>
<td>B.t. tenebrionis</td>
</tr>
<tr>
<td>11B</td>
<td></td>
<td>B.t. israelensis</td>
</tr>
<tr>
<td>11C</td>
<td></td>
<td>B.t. kurstaki, B.t aizawai *</td>
</tr>
<tr>
<td>11D</td>
<td></td>
<td>B.t. sphaericus</td>
</tr>
<tr>
<td>11E</td>
<td></td>
<td>B.t. tolworthi</td>
</tr>
<tr>
<td>12A</td>
<td>Inhibition of oxidative phosphorylation, disrupters of ATP formation</td>
<td>organotin miticides</td>
</tr>
<tr>
<td>12B</td>
<td></td>
<td>diafenthiuron</td>
</tr>
<tr>
<td>13A</td>
<td>Uncoupler of oxidative phosphorylation via disruption of H proton gradient</td>
<td>chlorfenapyr</td>
</tr>
<tr>
<td>14A</td>
<td>Inhibition of magnesium stimulated ATPase</td>
<td>propargite</td>
</tr>
<tr>
<td>15A</td>
<td>Chitin biosynthesis inhibitors</td>
<td>acyl ureas</td>
</tr>
<tr>
<td>16A</td>
<td>Ecdysone agonists</td>
<td>tebufenozide and related</td>
</tr>
<tr>
<td>17A</td>
<td>Homopteran chitin biosynthesis inhibitors</td>
<td>buprofenz</td>
</tr>
<tr>
<td>18A</td>
<td>Unknown dipteran specific mode of action</td>
<td>cyromazine</td>
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<tr>
<td>19A</td>
<td>Octopaminergic agonist</td>
<td>amitraz</td>
</tr>
<tr>
<td>20A</td>
<td>Site II electron transport inhibitors</td>
<td>hydramethylnon</td>
</tr>
<tr>
<td>21A</td>
<td>Site I electron transport inhibitors</td>
<td>rotenone, METI acaricides</td>
</tr>
</tbody>
</table>

### Resistance management groups: Fungicides

Table 9. Fungicides listed by activity group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mode of action group</th>
<th>Chemical group</th>
<th>Active constituent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Benzimidazole</td>
<td>Benzimidazole</td>
<td>benomyl carbendazim thiabendazole thiophanate-methyl</td>
</tr>
<tr>
<td>B</td>
<td>Dicarboximide</td>
<td>Dicarboximide</td>
<td>iprodione procymidone vinclozolin</td>
</tr>
<tr>
<td>C</td>
<td>DMI</td>
<td>Imidazole, Piperazine, Pyridine, Pyrimidine, Triazole</td>
<td>imazalil prochloraz triforine pyriflox fenarimol bitertanol cyproconazole diclofluanid difenoconazole flusilazole flutriafol hexaconazole myclobutanil paclitaxol penconazole propiconazole tebuconazole triadimefon triadimenol triticonazole</td>
</tr>
<tr>
<td>D</td>
<td>Phenylamides</td>
<td>Acylamine, Oxazolidinone</td>
<td>benalaxyl furalaxyl metalaxyl metalaxyl-m oxadixyl</td>
</tr>
<tr>
<td>E</td>
<td>Morpholine</td>
<td>Morpholine</td>
<td>tridemorph</td>
</tr>
<tr>
<td>F</td>
<td>Phosphor-thiolate</td>
<td>Organo-phosphorous</td>
<td>pyrazophos</td>
</tr>
<tr>
<td>G</td>
<td>Oxathiin</td>
<td>Anilide</td>
<td>carboxin oxycarboxin</td>
</tr>
<tr>
<td>H</td>
<td>Hydroxy-pyrimidine</td>
<td>Pyrimidinol</td>
<td>bupiriminate dimethirimol</td>
</tr>
<tr>
<td>I</td>
<td>Anilinopyrimidine</td>
<td>Anilinopyrimidine</td>
<td>cyprodinil pyrimethanil</td>
</tr>
<tr>
<td>J</td>
<td>Hydroxyanilide</td>
<td>Hydroxanilide</td>
<td>fenhexamid</td>
</tr>
<tr>
<td>K</td>
<td>Strobilurin</td>
<td>Strobilurin</td>
<td>azoxystrobin kresoxim-methyl trifloxystrobin</td>
</tr>
<tr>
<td>L</td>
<td>Phenylpyroles</td>
<td>Phenylpyroles</td>
<td>fludioxonil</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>
| **Y** | Multi-site activity | Carbamate
Phosphonate
Inorganic
Dithiocarbamate
Phthalimide
Chlorophenyl
Quinone
Hydroxyquinoline
Pyradinamine
Cyclic imide | iodocarb
propamocarb
fosetyl-Al
phosphorous acid
copper (cuprous oxide)
copper (hydroxide)
copper (oxychloride)
iiodine
mercury
sodium metabisulphite
sulphur
mancozeb
metiram
thiram
propineb
zineb
ziram
chlorothalonil
quintozene
dithianon
8-hydroxy quinoline
sulphate
fluazinam
captan |
| **X** | (Unspecified) | Cinnamic acid derivative
Sulfamide
Dinitrophenyl
Organophosphate
Guanidine
Thiadiazole
Quinoxaline | dimethormorph
dichlofluanid
tolyfluanid
dinocap
tolclofos-methyl
dodine
guazatine
etridiazole
oxythioquinox
pencycuron |
# Resistance management groups: Herbicides

Table 10. Herbicides listed by activity group

<table>
<thead>
<tr>
<th>Group</th>
<th>Mode of action group</th>
<th>Chemical group</th>
<th>Active constituent</th>
</tr>
</thead>
</table>
| **A** | Inhibitors of acetyl coA carboxylase  
(Inhibitors of fat synthesis/ACC’ase inhibitors) | Aryloxyphenoxy-propionates  
(‘Fops’)  
Cyclohexanediones (‘Dims’) | diclofop-methyl  
fluazifop-butyl  
haloxyfop-ethoxy-ethyl  
quizarofop-p-ethyl  
propaquizafop  
sethoxydim  
tralkoxydim  
cycloxydim  
clethodim |
| **B** | Inhibitors of acetolactate synthase  
(ALS inhibitors) | Sulfonylureas  
Imidazolinones  
Sulfonamides | chlorsulfuron  
halosulfuron-methyl  
metsulfuron-methyl  
rimsulfuron  
sufosulfuron  
triasulfuron  
bensulfuron-methyl  
thifensulfuron-methyl  
sulfometuron-methyl  
imazethapyr  
imazamox |
| **C** | Inhibitors of photo-synthesis at photosystem II | Triazines  
Triazinones  
Ureas  
Nitriles  
Benzothiadiazoles  
Acetamides  
Uracils  
Pyridazinone  
Phenyldiazaprazine | ametryn  
 atrazine  
simazine  
cyanazine  
terbutryn  
prometryn  
propazine  
metribuzin  
hexazinone  
diuron  
linuron  
metoxuron  
siduron  
ethidimuron  
methabenzthiazuron  
flumethuron  
tebuthiuron  
methazole  
bromoxylnil  
ioxynil  
bentazone  
propanil  
bromacil  
terbacil  
chloridazon  
pyridate |
| **D** | Inhibitors of tubulin formation | Dinitroanilines  
Benzoic acid  
Pyridines | trifluralin  
oryzalin  
pendimethalin  
benfluralin  
chlorothal  
thiazopyr |
<table>
<thead>
<tr>
<th><strong>E</strong></th>
<th>Inhibitors of mitosis</th>
<th>Carbamate</th>
<th>Chlorpropamid</th>
<th>EPTC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Thiocarbamates</td>
<td>chlorpropamid</td>
<td>Vernolate</td>
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<tr>
<td></td>
<td></td>
<td>Organophosphorus</td>
<td>tri-allate</td>
<td>Molinate</td>
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<td></td>
<td></td>
<td></td>
<td>pebulate</td>
<td>Bensulide</td>
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<tr>
<td><strong>F</strong></td>
<td>Inhibitors of carotenoid biosynthesis</td>
<td>Nicotinanilides</td>
<td>Diflufenican</td>
<td>Amitrole</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Triazoles</td>
<td>Norflurazon</td>
<td>Benzofenap</td>
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<tr>
<td></td>
<td></td>
<td>Pyridazinone</td>
<td>Clomazone</td>
<td>Isoxaflutole</td>
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<tr>
<td></td>
<td></td>
<td>Pyrazoles</td>
<td>Aryl triazolinones</td>
<td>Isoxazolidinones</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isoxazoles</td>
<td>Isoxazoles</td>
<td>Isoxazoles</td>
</tr>
<tr>
<td><strong>G</strong></td>
<td>Inhibitors of protoporphyrinogen oxidase</td>
<td>Diphenyl ethers</td>
<td>Acifluorfen</td>
<td>Carfentrazone-ethyl</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxadiazole</td>
<td>Oxyfluorfen</td>
<td>Oxyfluorfen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxadiazonoxadiargyl</td>
<td></td>
</tr>
<tr>
<td><strong>H</strong></td>
<td>Inhibitors of protein synthesis</td>
<td>Thiocarbamate</td>
<td>Thiobencarb</td>
<td></td>
</tr>
<tr>
<td><strong>I</strong></td>
<td>Disruptors of plant cell growth</td>
<td>Phenoxys</td>
<td>2,4-D</td>
<td>2,4-DB</td>
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<tr>
<td></td>
<td></td>
<td>Benzoic acid</td>
<td>MCPA</td>
<td>MCPB</td>
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<tr>
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<td></td>
<td>Pyridines</td>
<td>Dichlorprop</td>
<td>Mecoprop</td>
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<td></td>
<td></td>
<td>Picloram</td>
<td>Clopyralid</td>
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<td></td>
<td></td>
<td>Flouxypyr</td>
<td>Triclopyr</td>
</tr>
<tr>
<td><strong>J</strong></td>
<td>Inhibitors of fat synthesis</td>
<td>Alkanoic acids</td>
<td>2,2-DPA</td>
<td>Fluropropanate</td>
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<tr>
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<td>TCA</td>
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</tr>
<tr>
<td><strong>K</strong></td>
<td>Herbicides with diverse sites of action</td>
<td>Amides</td>
<td>Difenamid</td>
<td>Metolachlor</td>
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<tr>
<td></td>
<td></td>
<td>Organoarsenic</td>
<td>Propachlor</td>
<td>Propyzamide</td>
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<td>Carbamates</td>
<td>MSMA</td>
<td>Asulam</td>
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<td>Amino propionates</td>
<td>Phenmedipham</td>
<td>Flamprop-methyl</td>
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<td></td>
<td></td>
<td>Benzofurans</td>
<td>Ethofumesate</td>
<td>Naptalam</td>
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<td></td>
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<td>Phthalamates</td>
<td>Dichlobenil</td>
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<tr>
<td><strong>L</strong></td>
<td>Inhibitors of photo-synthesis at photosystem I</td>
<td>Bipyridyls</td>
<td>Paraquat</td>
<td>Diquat</td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>Inhibitors of EPSP synthase</td>
<td>Glycines</td>
<td>Glyphosate</td>
<td>Glyphosate-trimesium</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>Inhibitors of glutamine synthase</td>
<td>Glycines</td>
<td>Glufosinate-ammonium</td>
<td></td>
</tr>
</tbody>
</table>

Notes...
Notes...
Notes...