

# ***SPRAYpak***



## **Cotton Growers' Spray Application Handbook**

2nd edition



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**Cotton Research and Development Corporation**

**2002**

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## **SPRAYpak - Cotton Growers Spray Application Handbook**

2nd Edition

Editors: Ian Rankine and Peter Hughes

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## **Best Management Practices (BMP)**

SPRAYpak forms a part of the cotton industry's commitment to BMP in all facets of cotton production. It is complementary to the BMP manual, which outlines growers' legal responsibilities for pesticide use, and recommendations to help growers to meet those obligations. The BMP process allows growers to assess their performance regarding pesticide handling, storage and use and from those assessments, to develop action plans to improve practices and reduce risk.

Always read and follow instructions and warnings contained on the product label and MSDS for pesticides and other products being used.

Always read the operating manual and follow the manufacturers advice and safety guidelines when operating machinery.

Information contained in this publication is provided as general advice only, and professional specialist advice should be sought for specific circumstances.

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2. Information sources
3. Risk Management
4. Pesticide Fate Processes
5. Bureau of Meteorology Meteograms

# Foreword

Pest management is an integral part of cotton production in Australia. However, when handling, using and disposing of pesticides, the safety of people and the environment must be a primary consideration. It is an offence to let a pesticide contaminate another person, their property or the environment. Everyone involved in the pesticide supply, transport, application and disposal chain must act responsibly when making decisions about pesticide application.

SPRAYpak has been developed for growers and focuses on pesticide application and usage in cotton. However, the principles apply to all similar spray application jobs in agriculture. It is part of the industry commitment to BMP and should be used in conjunction with the current Australian Cotton Industry 'Best Management Practices Manual'.

A key aim of Best Management Practices (BMP) is to ensure that adverse off-target and environmental impacts of cotton production are kept to a minimum. Pesticide transport, usage and disposal all have associated hazards, and these must be managed to minimise risks of adverse outcomes.

To minimise the risk of harm to the environment or to human health, all personnel who are involved in pesticide usage and disposal must manage their operations with '**due diligence**'. Due diligence simply means to take care. But taking care also includes living up to the community's expectation of you as a grower or manager to:

- Act responsibly in all your activities and decision making processes,
- Be aware of local, State and National legislation, issues and decisions that affect your activities,
- Make decisions and undertake activities with a long term view, paying special attention to activities which have the potential for significant environmental impacts,
- Test all assumptions before undertaking an activity or making a decision,
- Be aware of and comply with your legal obligations as a grower and/or pesticide applicator. Ignorance of the law is not a defence.



Photo: Groundrig Operators Association Inc.



# Summary

SPRAYpak provides practical information on pesticide application to growers, applicators and other personnel in the cotton industry.

The handbook layout has been designed to place the sections containing the most frequently used information at the front of the handbook. The more detailed, technical sections follow in later sections. Each section and the general layout aim to follow a practical format so that readers can relate the information to their own situation.

This edition contains more illustrations and tables than the first edition, and wherever possible a 'summary' table of the important information has been included. In addition, many of the illustrations and tables are colour coded so that a preferred option can be clearly identified. The colour coding is as follows:

**Best option for most situations.**

**Preferred option to optimise application and reduce risk.**

**Suitable option for spray application but caution required.**

**Extreme caution and monitoring required.**

**This option is NOT RECOMMENDED.**

*Note: The BCPC nozzle classifications colours are different to the above.*

The colour coding in SPRAYpak should be used as a guide only, and each situation should be assessed individually in order to achieve optimum pesticide application within BMP guidelines. In all cases the manufacturers guidelines should be followed and, if necessary professional advice sought. Other growers, consultants and suppliers can provide local advice based on experience and the latest information from manufacturers.

These changes to SPRAYpak also assist in training programs so that all personnel can understand the content.

Additional details on specific sections and useful information are contained in the Appendices and the list of information sources.



SPRAYpak is a field handbook that integrates with components of BMP as shown below:

<b>BMP</b>	<b><u>Relevant SPRAYpak sections.</u></b>
APPLICATION OF PESTICIDES	All sections.
STORAGE AND HANDLING OF PESTICIDES	Section 6 - Pesticides. Section 7 - Equipment.
INTEGRATED PEST MANAGEMENT	Section 2 - Planning spray applications. Section 5 - Targets. Section 6 - Pesticides.
FARM DESIGN & MANAGEMENT	Section 2 - Planning. Section 3 - Managing spray applications.
FARM HYGIENE	Section 7 - Equipment
RISK MANAGEMENT	All sections Appendix

SPRAYpak contains seven main sections. These are summarized below:

## 1. Introduction

A short introduction to the handbook and individual sections.

## 2. Planning spray applications

Proper planning is the most fundamental prerequisite of effective pesticide applications. The cornerstone of effective planning is the development of a comprehensive pesticide application management plan (PAMP) covering the following:

- Farm layout and planning
- Identification of sensitive areas, potential hazards and awareness zones
- Communication procedures
- Pesticide management guidelines
- Accident and emergency procedures.

Pre-season planning between growers, neighbours, consultants, workers and applicators is essential to develop workable strategies for the season. Regular review of these plans and agreements is an important part of the best management practice (BMP) program in cotton. Similarly, pre-season



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checks of spray equipment, personal protective equipment (PPE), emergency kits and stores will often prevent problems, downtime and accidents during the season.

Communication channels must be maintained for participants in the application process and with neighbours and other people who may be in the PAMP area (See Section 2.1.1). Constant communication and review of procedures with these people is essential to identify weaknesses in the PAMP and to formulate better operating procedures.

Relevant training of all farm personnel, so that they contribute to BMP, is an integral part of effective, safe pesticide spraying and must be part of the planning and management processes.

### 3. Managing spray applications

A PAMP will help to ensure that everyone involved in pesticide application has a clear understanding of their responsibilities.

Pesticide selection for each spray must be based on accurate field checking and information provided by suppliers and crop consultants. Consideration should be given to all pest control strategies as part of an Integrated Pest Management (IPM) plan to minimise risk whilst still controlling the target pest. Similarly, when the pest management strategy decision includes spraying, the method of application should aim to maximise effectiveness whilst minimising the risks to personnel and the environment.

Once the control method has been established, each stage of control should be closely monitored to ensure that BMP and PAMP guidelines are being met.

Weather conditions play a critical role in pesticide application and other pest control strategies. Therefore, proper monitoring of conditions before, during and after the application is critical. During spray applications the following key meteorological conditions should be monitored and recorded:

- Wind speed - Spraying should only be done if wind speed is between 3 km/hr and 15 km/hr ( 0.8 - 4.2 m/sec) and relatively steady,
- Wind direction - Take additional precautions if the wind direction is towards environmentally sensitive non-target areas. In addition, consider chemical odours which may persist after the spraying has been completed,
- Atmospheric stability, turbulence, local wind effects, surface temperature inversion layers, changes in wind effects and any changes that occur whilst spraying is being undertaken,
- Temperature - Generally, optimum temperatures for spraying water based mixtures are less than 28°C. Risks of reduced efficacy and off-target movement increase at temperatures greater than 28°C. Spraying should proceed with caution at temperatures greater than 28°C and applicators should exercise extreme care if the ambient air temperature at the application site exceeds 30°C,
- Relative Humidity - It is preferable to spray in conditions where the relative humidity is greater than 45%,
- Rainfall - Do not spray if rainfall is imminent. Rainfall during or within 48 hours after application may reduce efficacy and/or move the pesticide off-target.

**Be prepared to stop spraying if conditions change and become unsuitable.**

After completion, each application should be reviewed and improvements made (if required) to the PAMP.



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Spray drift is a major hazard associated with pesticide application. Awareness of the causes of drift and how to minimise or eliminate drift are part of due diligence.

Buffer zones (buffers) assist in preventing off-target deposition either by providing a physical barrier that filters out the droplets and/or an area of land or crop to separate the sprayed area from sensitive areas. Vegetative buffers, such as tree lines, often form part of a sound environmental conservation program on farms, and add value to the property.

It is critical to ensure that the application and conditions are actually observed and recorded properly. It is also important that the observer has the knowledge and authority to assess the conditions, delay the spray if necessary and maintain communication and co-ordination until the application has been completed. Risks can be reduced if positive action is taken promptly. This includes implementing the correct procedures in the event of a spill, accident or complaint.

## 4. Record keeping

Efficient record keeping is an essential part of pesticide management to BMP standards. The minimum information that must be recorded for each application is:

- Date and times of application (including start, refilling and finish times),
- Persons authorising and supervising the application,
- Details of property owner, appointed representative and contact numbers,
- Property, field, crop and area (hectares) details,
- Pest details (or reference to a field check sheet),
- Chemical names, type (e.g. ULV), application rates, spray/water volumes,
- Applicators name and equipment operators name,
- Method of application, equipment, nozzle configuration and specific equipment setup,
- Operating pressures and other relevant information, including any changes that were made during the application,
- Meteorological conditions (including before, during and after the application),
- Operating conditions and any other observations,
- Compliance with PAMP/BMP guidelines and checks.

To satisfy specific State or National Legislation requirements, these records may have to be supplemented with additional information. Such recording requirements for specific pesticides are usually included on the label.

As part of the BMP process, the following records that are relevant to pesticide application should also be maintained:

- Notes of meetings conducted as part of the BMP/PAMP process,
- A register (list) of personnel training, refresher courses and accreditation gained,
- Details of equipment checks and calibration,
- Agreed notification arrangements and records of notifications (spray advice notices) during the season,
- Details of delayed or postponed spray applications,
- Records of complaints, accidents, spills and operational errors, and what remedial action was taken,
- Corrections or updates made to the PAMP.



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Records of chemicals stored on-farm and the relevant labels and MSDS should be maintained so that they are readily accessible by all personnel. Label information and MSDS can be obtained from product manufacturers and suppliers.

As with any relevant on-farm records, the maintenance of accurate pesticide and spray records may assist a grower to examine seasonal trends, provide information in the event of a spray failure or complaint, and, if incorporated with financial data, provide the basis for future improvement.

## **5. The Target**

Generally, target identification is done by consultants and/or agronomists in consultation with the grower. It is important that personnel involved in the spraying have an understanding of how the target influences pesticide type and formulation, and equipment selection. This section of the SPRAYpak handbook provides a brief outline of the factors which must be considered when assessing a pest target which has to be sprayed.

For more detailed information on insect pests and target identification, growers should refer to ENTopak 'A compendium of information on insects in cotton' which is produced by the Australian Cotton Cooperative Research Centre (Cotton CRC).

## **6. Pesticides**

This section of SPRAYpak provides guidelines on the important aspects of pesticides and their responsible use so that growers can incorporate these considerations into their BMP program.

Topics covered in this section include:

- Pesticide formulations
- Labels
- Material Safety Data Sheets (MSDS)
- Transport
- Safe storage
- Pesticide mixing
- Personal protective equipment (PPE)
- Monitoring personnel
- Poisoning
- Pesticide residues
- Disposal of containers and unused pesticides
- Pesticide spills and clean-up procedures
- Spray failures
- Legislation pertaining to pesticides.

## **7. Spray equipment**

This section of SPRAYpak includes the following topics:

- Ground application equipment
- Calibration of ground rigs
- Guidelines on ground rig set-up for different spray applications
- Aerial application equipment



- Aerial application methods
- Nozzles and outlets
- Getting the best from your nozzles
- Droplet formation, transmission and capture
- Droplet size and how this influences spraying decisions
- Analysing spray applications
- Marking and positioning systems
- Pumps and ancilliary equipment
- Cleaning and decontamination of equipment.

Pesticide usage is one of the activities in cotton farming with the greatest potential to cause off-target and/or environmental contamination or damage. It is also one of the areas of greatest recurrent expenditure in cotton growing. Therefore, it makes sense to ensure that knowledge and farming practices are improved to optimise pesticide applications.

SPRAYpak provides guidelines on aspects of spray equipment that are relevant to BMP and effective spray application. Engineering and performance details of individual pieces of equipment or accessories can be obtained from the manufacturers or their agents.

## Appendices

1. Useful unit conversions.
2. Information sources.
3. Risk management.
4. Pesticide fate processes.
5. Bureau of Meteorology meteograms.

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### **Remember:**

- You are expected to have knowledge of the laws and any correct practices relating to pesticide acquisition, storage, usage and disposal.
- It is illegal to use a pesticide that is not registered or subject to a current National Registration Authority (NRA) permit.
- In New South Wales, it is an offence to pollute waters.
- The New South Wales Pesticides Act creates offences for off-farm damage to people, property, plants and animals.
- In Queensland, farmers have a legal obligation to carry out their activities in a way that avoids environmental harm.
- The Queensland Chemical Usage Control Act requires pesticide users to follow label directions and to dispose of pesticides and pesticide containers in a way that does not harm people, property or the environment.
- Commercial applicators have particular legal requirements in Queensland.



# 1. Introduction

This SPRAYpak handbook provides cotton growers with a concise reference for spray application planning decisions. It builds on the foundations established with the first edition of SPRAYpak, but aims to incorporate additional information which has become available since the first edition was published in 1994.

SPRAYpak is designed as a practical field guide and as a reference document for the training of personnel. Detailed technical explanations and terminology have been kept to a minimum.

SPRAYpak is divided into seven main sections:-

Section 1 is the introduction. Sections 2, 3 and 4 cover the planning, managing and recording of effective spray applications, which are the most frequent field activities during the season. Reference to these sections will provide growers with practical information for safe, effective pesticide spraying. The sequence of the first three sections is in the order that they are generally done in the field. Planning is a prerequisite to effective management of spray applications, and proper recording an important step to complete each application.

Sections 5, 6 and 7 contain more detail on specific issues such as targets, insect pests, pesticides and application equipment to complement the first three sections. Growers and applicators can refer to these sections if they require more information on specific topics.

Proper identification of the target and its characteristics often determines not only the pesticide chemistry and formulation, but the best equipment and set-up for effective application. The section on targets does not attempt to describe all pests (including weeds) in every cotton growing area, but provides guidelines on the key characteristics which should be considered prior to selecting a pesticide type and application equipment.

Following on from target identification, the correct pesticide and equipment must be selected for each application, and Sections 6 and 7 provide more details of these.

Pesticides are essential to achieve the yields and quality of Australian cotton, and a thorough understanding of the products, formulations and safe handling procedures is essential to minimise the risk associated with their use. This handbook provides relevant information on pesticide formulations, labels, MSDS's, transport, storage, mixing, safety, personal protective equipment, safe disposal and management of spills.

Section 7 contains information on equipment that is most commonly used for spraying cotton in Australia. No pesticide application will be fully effective unless it is applied using the correct equipment that is calibrated and maintained properly. The section contains information on ground and aerial application, calibration, setting up equipment, nozzles and outlets, droplet formation and characteristics, pumps and other fittings and cleaning and decontamination. Methods of analysing spray applications and droplets are also included in this section.

SPRAYpak is one component of the best management practice program (BMP) which has been implemented in the Australian cotton industry. As with all components of BMP, the handbook is a guide to assist growers to develop their property-specific BMP programs in order to achieve high standards of responsible and sustainable cotton production.



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Macintyre	Goondiwindi	(07) 4671 6711	(07) 4671 2782	0428 879 900
Balonne	St. George	(07) 4625 3299	(07) 4625 3892	0408 710 969
Darling/Lachlan	Griffith	(02) 6960 1353	(02) 6963 0255	0427 107 057
Upper Namoi	Gunnedah	(02) 6742 9279	(02) 6742 2940	0427 007 422
Gwydir	Moree	(02) 6752 5111	(02) 6752 4859	
Macquarie	Warren	(02) 6847 4507	(02) 6847 3664	0408 447 483
Lower Namoi	Narrabri	(02) 6799 1500	(02) 6799 1582	
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## 2. Planning spray applications

Planning is the **first** step in any spraying operation. This section outlines the main points to consider (pre-season) so that a proper pesticide application management plan (PAMP) and operating procedures can be established.

Effective planning prevents many of the problems that occur as a result of pesticide application, including off target movement of droplets (i.e. spray drift).

Planning for spray application ranges from farm design (long term) to pesticide formulations and application methods (medium-short term). In some cases the general farm layout has been established and would be difficult to alter, but the crop rotations, variety selections and control of run-off can be managed effectively. For example: Consideration should be given to surrounding areas and crops when planning future farm crops so that off-target contamination is minimised.

### Spray application planning

- Spray planning is an integral part of BMP
- Pesticide Application and Management Plan (PAMP)
- Communication
- Commitment to responsible spraying practices
- Constant monitoring and improvement of plans and applications

## 2.1 Pesticide Application Management Plan (PAMP)

An effective pesticide application management plan (PAMP) will ensure that everyone involved in pesticide use has a clear understanding of their responsibilities. A PAMP will also help to identify the risks associated with pesticide handling and applications, so that risk controls can be put in place.

A complete PAMP forms a key part of best practice in any agricultural operation, and should be reviewed and improved as circumstances dictate.

An effective PAMP will ensure that:

- information exchange and communication are effective
- everyone involved has a clear understanding of their responsibilities
- risks associated with pesticide use are identified
- controls to minimise risks are implemented
- appropriate application techniques and procedures are used.

Key elements of an effective PAMP are:

### Maps

Accurate, up-to-date location maps showing details which may influence pesticide application decisions.



<b>Communication</b>	Effective communication procedures (including conflict resolution procedures).
<b>Information</b>	Relevant pesticide knowledge, application details and procedures.
<b>Risk management</b>	Identifying hazards and the associated risks and taking action to minimise those risks.

## 2.1.1 Maps

An accurate farm map is essential for all aspects of good management. Maps should be developed based on accurate ground based survey methods, accurate aerial photos, satellite imagery or a combination of these. Accurate maps are an essential part of BMP and the development of a proper PAMP. The maps should be made available to consultants and applicators and details should be checked prior to each season to ensure that all maps are consistent. It is very important to ensure that all field names are consistent and up to date, and that all entry and exit points are marked.

The following sections outline what should be included on the maps.

### Basic farm layout

A detailed, accurate base farm map is the basis for the PAMP. It is essential that all the relevant features of the target farm are included on the base map. Field (paddock) names and areas should be included on the base map and also listed in the PAMP under the farm details section.

The farm map should be updated annually, or more frequently if there are significant changes in the area covered by the PAMP. All maps should include a true North indicator, scale bar, legend and details of the property name, contacts, and UHF. The name and contact details of the map creator should be included for future reference.

Unlike a regular farm map, a PAMP map must include surrounding areas. As a guide, include at least a 3km zone around the boundaries and any sensitive areas to 5km.

### Farm buildings

All buildings that are included in the PAMP zone should be included in the map. This includes dwellings (houses), work or storage sheds, any urban buildings and buildings which may house livestock.

### Neighbouring properties

Plans of the neighbouring properties should be included in the PAMP map. Include as much detail as possible (e.g. field, crops and grazing areas) and observe changes so maps can be updated. Talk to your neighbours and obtain their input as part of the BMP process. Applicators should be made aware of which neighbours have not responded to BMP communications or have particular requirements under the PAMP process.

The distance to neighbouring properties and dwellings should be marked or be easily determined from the scale bar. If there is a group of properties (e.g. a town or suburb) these may be shown as a 'block' of similar risk assessment.



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Sensitive areas (e.g. water reserves) and locations (e.g. places where people live or work) must be very clearly highlighted.

Ensure that there is sufficient separation between areas which are to receive chemical applications and areas that may be affected by those chemicals.

### **Buffer zones**

Buffers are established to reduce potential adverse impacts of pesticide application such as drift. Buffers may be zones that separate the application area from sensitive areas, in-crop offsets or barriers (such as tree lines) which reduce off target impacts of the pesticide application.

Existing buffers including areas planted to Ingard®, should be identified on the map, and specific buffers (such as those required to apply endosulfan) should be clearly marked.

Note: The existence of a buffer does not guarantee that drift will not affect a sensitive area if the wind direction is towards the sensitive area during spray application.

### **High risk sectors**

High risk sectors identify areas that cannot be sprayed when certain conditions (e.g. wind speeds and directions) prevail. For example: If the wind direction is anywhere in a sector between North and East, and greater than 5 km/hr, no spraying is to be undertaken as it presents an unacceptable risk to a neighbouring township.

Identify areas that are particularly hazardous and under what conditions unacceptable risk is likely to occur. Identify potentially hazardous wind speeds and directions for each field.

Communicate this information to all personnel involved in spray operations and, if possible, mark the hazards on the PAMP map.

Clearly mark an 'awareness zone' on the maps to indicate the area which is covered by the PAMP. This zone indicates to employees and other personnel where PAMP considerations are relevant.

### **Roads and railways**

Public and private roads and rail tracks should be included on the PAMP map. Use of aerial photos will assist with the identification of private roads. Roads should be assessed in terms of volume and type of traffic and risk hazard. Public roads near schools and kindergartens will present a greater risk than a private road to a seldom-used quarry.

Rail lines will be readily identified in aerial photographs and details can be checked with local rail authorities.

Stock routes should be marked, and observed for activity during daily operations.

### **Bus, train and stock routes**

The routes for buses (e.g. school, tourist, and shift workers) and trains (e.g. freight, passenger, tourist) should be identified. The times when there is activity on each of these routes should be included the PAMP under the risk identification section.



## Water

All water courses, storages and drains must be included on the PAMP map. Dams, ponds, weirs and wildlife habitats should be clearly marked. The direction of water flow, both on-farm and in the surrounding drainage areas, should be indicated (this includes irrigation drainage).

## Other sensitive areas

Wildlife habitats, wetlands and alternative farming areas (e.g. organic production) must be clearly identified and mapped.

## Weather stations and windsocks

The location of weather monitoring stations and windsocks (or other wind direction indicators) should be clearly marked on the PAMP map.

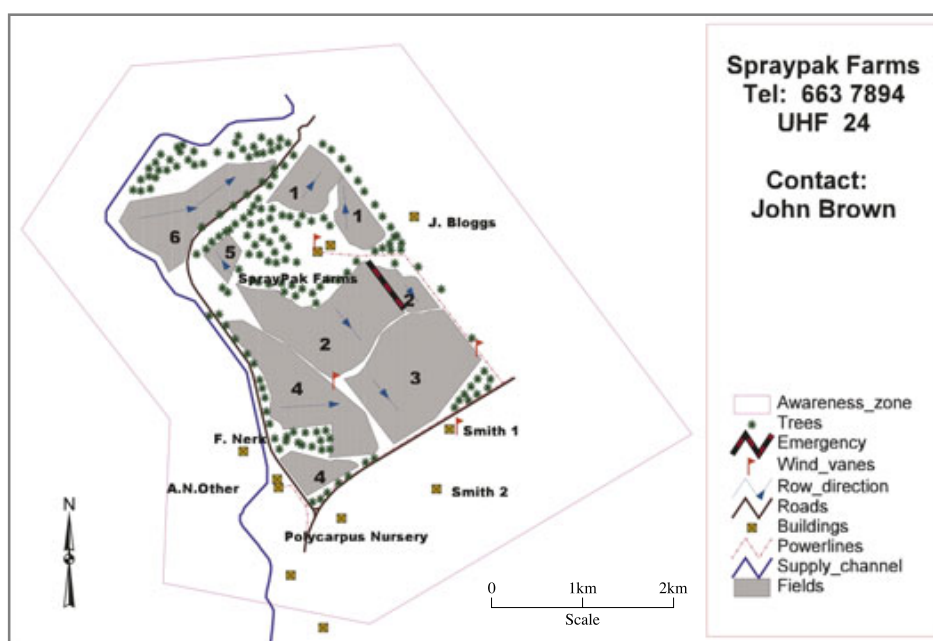
## Applicator hazards

Features that pose a hazard to applicators should be included on the map. These include:

- power lines, poles and towers and the stay wires for these structures,
- other utilities (e.g. intersection lighting poles) or features (e.g. silos),
- hills, mountains, gullies or other landscape features which may pose a risk,
- tall trees and other vegetation,
- sensitive crop areas,
- no-fly (no-go) zones.

If available, identification of an ‘emergency’ area where an aircraft could attempt an emergency landing and/or a ground applicator could implement emergency procedures would be helpful. Monitor, adapt and improve the PAMP as the season progresses to maintain BMP and minimise incidents.

**Fig. 2.1. An accurate map is an essential part of BMP.**



Source: 4T



## 2.2 Communication

Good communication is an essential part of a successful spray application and best practice farming. Any person entering the farm or residing within the PAMP and/or buffer zones should be informed of the farm practices and policies regarding pesticide management.

Accurate farm maps are essential during discussions so that key features of the farm and operations can be explained to other personnel.

### Communication

- Complete the PAMP and establish communication channels before the season starts.
- Awareness zone - identify who must be contacted within the zone.
- Communicate during all spray operations.
- Inform neighbours of important issues and any changes to the agreed PAMP.
- Encourage two-way communication.
- Discuss / summarise the season after picking is completed.

Communication should be an on-going process involving:

- employees
- neighbours
- consultants
- applicators
- contractors
- suppliers and sales personnel
- other persons who may enter your property (e.g. tractor mechanics).

### 2.2.1 What to communicate

Growers have a responsibility to communicate their plans to neighbours and personnel who may be involved (or present) during pesticide application so that any concerns can be reasonably considered in the PAMP. Action plans should be formulated following these discussions.

Discussions should include:

- Overall PAMP contents and procedures,
- Farm map(s),
- Sensitive areas and locations,
- Features and practices that pose a hazard during pesticide application,
- Conditions of entry to the farm during pesticide application and general BMP procedures (e.g. farm hygiene, 'Come Clean - Go Clean'),
- Emergency procedures (e.g. in the event of a pesticide spill),



- Contact names and numbers (i.e. telephone, UHF) for the farm, neighbours and external personnel,
- Locations of cropping and grazing areas,
- In-season neighbour notification requirements,
- Stop-Go procedures to apply, delay or abort a pesticide application,
- Procedures for handling complaints,
- Information about pesticide types and MSDS should be an on-going process of education with farm personnel,
- The weather conditions that are acceptable for spraying,
- End-of-season review of problems and inadequacies with the current PAMP, and improvements for the following season.

Communication must be maintained throughout the season to constantly adapt and improve procedures to meet BMP objectives. Refer to the ‘Application of Pesticides’ section in your BMP manual.

All personnel entering the farm or involved in associated activities must follow reasonable instructions from the grower (or authorised representative) to ensure that all pesticide applications follow risk minimisation guidelines.

## 2.2.2 Who to communicate with

### Employees

All employees must be familiar with the PAMP and understand the procedures for pesticide applications.

It is important that employees understand the particular properties of the pesticides that they will be handling, and the necessary safety precautions. In the absence of the farm owner, responsibility must be delegated so that pesticide application procedures are followed.

Emergency procedures and responsibilities must be planned and understood.

### Neighbours

Communicate PAMP details and seek collaboration with neighbours prior to the cotton season.

Agreed arrangements for neighbour notifications need to be followed during the season. A mid-season check to ensure that procedures are appropriate should be made (even if the PAMP arrangement is that notification need not be given).

In some cases, communication can be difficult, but in all cases it is essential and a genuine commitment to BMP will often assist in the development of trust.

### Consultants

Consultants play a key role in pesticide applications, and they need to have a clear understanding of the farm PAMP. The grower and consultant both need to be aware of every application decision, including the timing and method(s).



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People who are authorised to provide recommendations and information regarding pesticide applications must be identified during the PAMP planning process.

In addition to the key PAMP components, the grower and consultant must liaise closely on the following matters regarding pesticide application:

<b>Who</b>	Makes the decision on chemical selection and application method.
	Orders the application and arranges notification.
	Makes the final decision on whether the application proceeds, is delayed or aborted.
<b>How</b>	Is notification of the application made.
	Complaints, delays and resprays are handled.
	Post application details are followed up.
	Neighbours and others are notified.
<b>What</b>	Pest and damage thresholds are to be used.
	Written format is the crop (pest) report to be submitted in by the consultant prior to application.
	Sensitive areas and buffer zones need to be considered.
	Special restrictions apply for the pesticide or application method.
	Procedures are followed in the event of a delayed or aborted spray application.

## Applicators

Applicators must have a clear understanding of the farm PAMP and any special conditions in force in the area to be sprayed. The grower and applicator need to discuss application procedures in detail, and application requests should be provided in writing.

Discussions with aerial operators should include details about their participation in Operation Spray Safe.

A PAMP map is essential for all applicators (including farm employees) and must include hazards, sensitive areas, emergency areas (e.g. landings) and special conditions. The map features must be discussed and identified pre-season.

In addition to the key PAMP components, the grower and applicators must liaise closely on the following matters regarding pesticide application:

<b>Who</b>	Makes the decision on chemical selection and application method.
	Are the contact personnel and what are the communication plans for applications.
	Makes the final decision on whether the application proceeds, is delayed or aborted.



## How

Is notification of the application made.

Complaints, delays and resprays are handled.

Post application details are followed up.

Neighbours and others are notified.

Records are completed and handled.

## What

Formats are required for application requests, spray records and follow up reports.

Sensitive areas and buffer zones need to be considered.

Hazards require additional care on or near the farm.

Special restrictions are in place for the pesticide application.

Procedures are followed in the event of a delayed or aborted spray application.

Are the weather conditions and forecasts.

A three-way meeting between grower, applicator and consultant is the best way to ensure that all key parties are fully aware of procedures and responsibilities. This would also save time and allow problems to be discussed prior to the season.

## Contractors

Contractors must have a clear understanding of the farm PAMP as part of the BMP process. The contractors must agree to the farm BMP guidelines and any special conditions in force prior to entering the property. Contractors (e.g. cotton chippers) should also implement their own procedures to ensure that they and their employees are aware of relevant legislation and sections of the BMP program.

## Suppliers (including service providers)

Suppliers must have a clear understanding of the farm PAMP as part of the BMP program. The suppliers must agree to the farm BMP guidelines and any special conditions in force prior to entering the property. Chemical suppliers have an important role to ensure that details of pesticides and MSDS are made available to growers and applicators on first supply or request.



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### **Aerial Agricultural Association of Australia. (AAAA)**

AAAA has a certification program called Operation Spray Safe. It requires aircraft operators to employ approved pilots, to use aircraft and equipment of an approved standard and adhere to environmental and workplace health and safety regulations.

For more information, contact your aerial operator or:

The Executive Officer  
Aerial Agricultural Association of Australia  
PO Box 647  
Dickson ACT 2390

Tel: 02 6262 8256      Fax: 02 6262 8257      eMail: [phil@aerialag.com.au](mailto:phil@aerialag.com.au)

### **Groundrig Operators Association Inc. (GOA)**

GOA assists groundrig owners with information, support and training to ensure a high standard of pesticide application.

For more information, contact your groundrig operator or:

The Executive Officer  
Groundrig Operators Association Inc.  
PO Box 845  
Moree NSW 2400

Tel: 02 6752 9167      Fax: 02 6752 9070      eMail: [hzilm@groundrig.com.au](mailto:hzilm@groundrig.com.au)

### **Cotton Consultants Australia Inc. (CCA)**

CCA has developed a certification program for members which includes training in relevant elements of the BMP program.

For more information, contact your consultant or:

The Executive Officer  
Cotton Consultants Australia Inc.  
PO Box 508  
Narrabri NSW 2390

Tel: 02 6792 5459      Fax: 02 6792 5461      eMail: [ccaao@northnet.com.au](mailto:ccaao@northnet.com.au)



## 2.3 Integrated Pest Management (IPM)

An integral part of BMP and the PAMP process is the reduction of dependence on synthetic chemicals through integration with other forms of control. Due consideration should be given to:

- Variety selection,
- Bt cotton,
- Sowing dates,
- Nutrition and irrigation programs,
- Use of plant growth regulators,
- Rotation crops and programs,
- Pupae busting and other cultivation methods,
- Field selection,
- Use of refuges and trap crops,
- Thresholds and pest damage tolerances,
- Use of biological pesticides to reduce the impact on beneficial insects and the environment,
- Involvement in area-wide management strategies.

Use of these strategies will affect spray application plans, and the BMP process on individual properties. Refer to:

‘Cotton Pest Management Guide’ which is published annually by NSW Agriculture and Australian Cotton CRC, NSW, Australia.

‘IPM Guidelines for Cotton’ in ENTopak, available from Cotton CRC’s Technology Resource Centre, Cotton Research Institute, Australia.

### 2.3.1 Insecticide Resistance Management Strategy

Insect resistance management strategies have been developed by the Transgenic and Insect Management Strategy (TIMS) Committee of the Australian Cotton Growers Research Association. The strategies for individual cotton growing areas are reviewed and updated each year, and copies of the current strategy plans are distributed to growers, consultants, researchers and other personnel in the cotton industry. The plans are also included in the ‘Cotton Pest Management Guide’ produced by the Australian Cotton Cooperative Research Centre.

The main objective is to promote strategic pesticide usage to minimise the development of insect resistance. The recommendations contained in the TIMS reference cards should be incorporated into any seasonal pesticide application management plans.

## 2.4 Agreements

During PAMP development, it is good practice to ask participants (e.g. neighbours, consultants, applicators etc.) to sign a statement that the relevant sections have been discussed, adjusted to accommodate special requirements and agreed.



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By signing, each participant acknowledges that they understand the PAMP, that they have been given an opportunity to contribute, and that they agree to co-operate with the plan guidelines.

## **2.5 Equipment checks**

Before the season begins, check all pesticide application, storage, handling and monitoring equipment to ensure that it is in good working order and avoid expensive downtime.

### **Application equipment**

Run the equipment at operating pressure using clean water, and repair or replace faulty parts. Repair any leaks and check for worn parts that may fail during the season to ensure that spares can be obtained. The booms, lines, valves and outlets should be given thorough inspections, and nozzle output checks should be conducted.

GPS equipment should be checked, maintained and calibrated.

Controlled atmosphere equipment (CAE) such as carbon impregnated cab filters should be checked. If in doubt - renew it prior to the main spraying season.

Personal protective equipment (PPE) must be checked and replaced if damaged or out-of-date. Ensure that there are sufficient items for all personnel who will be exposed to contamination hazards. Wash facilities should be checked, cleaned and clean water storages refilled. Check that there are appropriate storage and decontamination facilities for PPE so that it can be safely used at any time.

### **Emergency equipment**

Personal wash down bays, eye rinses and first aid kits should be checked. Emergency spill kits should be unpacked, inspected, replenished and repacked. Fire control equipment should be checked.

Check that emergency contact lists and numbers are up to date. Check emergency landing areas (if applicable).

### **Meteorological equipment**

Weather stations and other meteorological equipment (e.g. handheld wind speed indicators) should be checked against other calibrated equipment. Ensure that calibration and service schedules are up-to-date.

### **Storage and handling equipment**

Storage facilities should be checked for security and maintenance and repaired as necessary to maintain BMP standards. Pumps, flow meters, lines and valves should all be tested at working pressures using clean water. Spill containment bunds, gates and locks should all be intact and sound.

### **Communication equipment**

All equipment (such as UHF radios) to be used for communicating during applications should be tested and maintained. Checks should be conducted with operators, consultants and contractors if these have not been continuously in use since the last growing season.



Ensure that all equipment checks are recorded and, if possible, record the dates of inspection on the equipment or facility. Check that all warning, hazard and emergency signs are in place and clear.

## 2.6 Recording systems check

Review the PAMP and ensure that all personnel are aware of record keeping requirements.

Spray order and monitoring forms may have to be updated to reflect changes in recording requirements since the last season.

Weather recording systems should be consistent with BMP requirements and data should be accessible to key personnel during spray applications.

Machine, pesticide storage/usage and personnel recording systems should be up-to-date. Refer to Section 7 for more information on equipment set-up and maintenance.

## 2.7 Information sources for planning

### Meetings

Cotton Australia and suppliers facilitate meetings to inform all industry personnel about the BMP program. Area-wide management groups of neighbouring farmers hold meetings to discuss best practices on their farms.

### Information bulletins

The cotton industry is well serviced with publications and bulletins. Government agencies and suppliers also provide detailed information on new pesticides and application methods. Many industry websites also have useful information which is updated regularly. Refer to Appendix 2.

### Government agencies

Government agencies provide information on their research programs and legislative changes. The BMP manual has brief summaries of legislative responsibilities, and reference lists if more detailed information is required.

### Consultants

Consultants have accumulated knowledge and local experience. Cotton Consultants Australia (CCA) has established an accreditation program to improve the knowledge of consultants and their personnel.

### Maps

Basic maps, aerial photographs or satellite images can usually be purchased from relevant State or Local Government offices.

### Commercial operators

Commercial operators and contractors have extensive local knowledge and are an integral part of any spray planning.



## 2.8 Training

Obtaining suitable accreditation ensures that spray operators and personnel involved in spraying operations are more aware of the hazards and are trained to minimise risks. Suitable training and accreditation ensures that all personnel can contribute to safer, more effective spraying. Accreditation is mandatory to obtain some chemicals.

Aerial operators, pilots and commercial ground applicators must be licensed according to Federal, State and/or Territory regulatory requirements and be properly trained.

For more information regarding accreditation and training:

### **National**

Executive Manager  
ChemCert Australia Inc.  
PO Box E10  
KINGSTON 2604  
ACT

Tel: (02) 6933 2177 Fax: (02) 6933 2924

### **New South Wales**

Australian Centre for Agricultural Health and Safety  
University of Sydney  
PO Box 256  
MOREE 2400

Tel: (02) 6752 8210 Fax: (02) 6752 6639

Executive Officer  
ChemCert Training (NSW)  
249 Bronte Road  
WAVERLEY 2024

Tel: (02) 9387 4714 Fax: (02) 9387 4746

National Secretariat  
ChemCert Australia Inc.  
C/- Farrer Centre  
Charles Stuart University  
Locked Bag 588  
WAGGA WAGGA 2678

Tel: (02) 6933 2177 Fax: (02) 6933 2924

NSW Farmers Group Training Co.  
GPO Box 1068  
SYDNEY 2001

Tel: (02) 9251 1700 Fax: (02) 9231 5249



**Queensland**

ChemCert Training Qld  
PO Box 17  
GRANGE 4051

Tel: (07) 3352 5033 Fax: (07) 3352 5042

Farmsafe Queensland  
PO Box 785  
THURINGOWA 4817

Tel: (07) 4774 0522 Fax: (07) 4774 0289  
Freecall: 1 800 818 006

**Northern Territory**

School of Horticulture and Landcare Studies  
Building 40  
Casuarina Campus  
DARWIN 0909

Tel: (08) 8946 6328 Fax: (08) 8946 6690

**Cotton Australia Limited**

Level 2, 490 Crown Street  
SURRY HILLS 2010  
NSW

Tel: (02) 6792 5459 Fax: (02) 6792 5461

Website: [www.cottonaustralia.com.au](http://www.cottonaustralia.com.au)

**Cotton Australia - Regional Offices**

<b>Emerald</b>	Tel: (07) 4982 0611	Fax: (07) 4982 0511
<b>Dalby</b>	Tel: (07) 4669 6288	Fax: (07) 4669 6299
<b>Goondiwindi</b>	Tel: (07) 4671 5965	Fax: (07) 4671 5978
<b>Narrabri</b>	Tel: (02) 6792 6041	Fax: (02) 6792 6042
<b>Warren</b>	Tel: (02) 6847 3688	Fax: (02) 6847 3755



## 3. Managing spray applications

This section covers aspects to be considered during spray applications, to ensure the safety of personnel and the environment. It is an offence for a grower to let any pesticide (which is being used on their property) contaminate another person, their property, or the environment.

If a pesticide cannot be applied safely then the application must be delayed, or an alternative product used which can be applied safely.

### 3.1 Pesticide Application Management Plan (PAMP)

The PAMP is fundamental to the effective management of pesticide applications in cotton. It should be completed well before the season starts so everyone involved in the application of pesticides is aware of their responsibilities and responses if problems arise.

Ensure that everyone involved in pesticide application understands the PAMP and the communication procedures so that the best decisions can be made and responses implemented.

Agreed procedures should be followed, or if adapted, the changes should be communicated effectively. The risk analysis component of the PAMP will identify hazards so that effective monitoring of spraying operations can be maintained.

### 3.2 Pesticide selection

Seek the advice of consultants and suppliers on the type of pesticide and formulation that is best suited to the situation and prevailing conditions. If the pesticide is a new product and/or formulation, ensure that all personnel involved with the preparation and application are familiar with the product label and relevant material safety data sheets (MSDS). Follow the label directions for applying the pesticide and observe any special restrictions or conditions.

#### Before selecting a chemical

- Does a pesticide need to be used or are there alternative control methods available?
- What are the risks associated with this product?
- Can a 'safer' product be used?
- Is band application an alternative to use less product and reduce risk?
- Assess risks associated with particular applications and select formulations and application methods that minimise those risks.

*For example: When applying pesticides near dwellings, provided that conditions are suitable, the use of a ground rig with droppers and low drift nozzles, and a low odour formulation may reduce the risk to residents.*



## Formulations

Cotton pesticides are available in many different formulations and the properties of these necessitate different handling and application techniques. Refer to Section 6.1 for more information on pesticide formulations.

Considerations such as cost, availability, compatibility with other pesticides, hazard (including odour) and suitability to equipment will determine the formulation that is used.

The formulation which is used will affect the risk associated with the application. For example, use of an EC formulation through low-drift nozzles instead of a ULV formulation through micronairs may reduce the risk of drift. Where new pesticides or mixtures are being used, advice should be sought from the product supplier and/or manufacturer.

## 3.3 Mixing pesticides

Refer to Section 6.7 for more details on mixing.

### Read the label

The first step in every case is to read the label and follow the directions.

#### Hazards - Mixing pesticides

Toxicity	Read the label and MSDS information. Ask your supplier.
Poisoning	Wear the appropriate PPE and follow safety directions.
Spillage	Observe safe handling and disposal procedures.
Flammability	Read the label and MSDS. No smoking or ignition sources.
Dosage	Read the label and use proper measuring equipment.
Contamination	Clean mixing equipment. Segregate pesticides properly.

**Always apply pesticides according to label recommendations.**

### Personnel training

All personnel should be trained in proper handling, mixing and application methods. There are a number of courses such as the Farmcare Chemical Users Course (ChemCert), FarmSafe, SMARTtrain or AgSafe, all of which are designed for farmers and personnel who use pesticides. Refer to Section 2.8 for groups to contact for training and accreditation courses.

Personnel who are involved in spraying should be trained in:

- Health and environmental hazards associated with pesticide use,
- Understanding labels and MSDS,
- Following directions,
- Safe Work Practices for the storage, handling and application of pesticides,
- Emergency procedures,



- First Aid procedures,
- Clean up procedures,
- Pesticide waste disposal options.

## **Water quality**

Water quality can affect the effectiveness of a pesticide. In some cases it can be of such poor quality that it can affect the efficacy of the product whilst still in the spray tank. Testing of water sources for pH and pesticide content is essential prior to using them for pesticide spraying. Refer to Section 6 for more information on water quality.

## **Agitation**

Whenever a solid active constituent is used (e.g. wettable powders, dispersable granules or suspension concentrates), good spray tank agitation is required to keep the spray mixture consistent. Failure to agitate will result in the active ingredient settling in the bottom of the spray tank during the spraying operation. Refer to Sections 6 and 7 for more information about correct agitation methods and equipment.

## **Use of adjuvants**

An adjuvant is any substance added to a spray mixture to modify its performance. It is usually added to enhance the performance of a pesticide or to overcome some inhibiting factor. Examples include wetting agents and buffering agents. Refer to Section 6 for more information on adjuvants.

# **3.4 Application orders**

Application orders (spray orders) should be completed in writing, in accordance with the PAMP guidelines that were established pre-season.

Application orders should be submitted to the applicator well in advance of the proposed spray date, and should include the following information:

- Date, order number, name of the property and person making the order, and BMP reference number,
- Consultant and crop check reference (if applicable),
- Location of the area (field) to be treated. A farm PAMP map should be attached to the application order with the areas to be treated clearly marked. Refer to Section 2 for details that should be included on the map.,
- Hazards that are not shown on the PAMP map but may be present during the application such as school bus runs, chipping crews, curfews,
- Crop and pest(s) to be treated,
- Contact person(s) and details in the event of a problem,
- Product to be used, pesticide rate, application volume, method of application and any specific application details (e.g. large droplet placement). Product details such as batch number may have to be recorded under specific State legislation.
- Post application considerations such as odours or rainfall should be noted on the order.



- Confirmation that the PAMP procedures have been followed, neighbours have been notified and, where applicable, that waivers have been provided,
- Requirements for notification that the job has been completed,
- Specific instructions that are necessary to ensure that the application adheres to BMP.

## 3.5 Application method

Considerations when selecting an application method include:

- Suitability of the equipment and set-up to the situation,
- Type of pest,
- Cost,
- Availability,
- Risk (i.e. proximity to hazards),
- Accessibility (eg. whether the fields have recently been watered),
- Type of pesticide (eg. pre-emergent incorporated pesticides),
- Specific label recommendations and requirements.

### Hazards - Application method

Equipment	Equipment should be well maintained and calibrated for each application.
Spray outlets	Use of incompatible or unsuitable outlets (nozzles) and equipment may lead to increased off-target deposition, less effective pest control and/or equipment failures.
Sensitive areas	Application method and chemical type should be selected with due consideration for surrounding areas.
PAMP	If pesticides are applied using methods that are not consistent with the PAMP, there may be increased risk of environmental or personal harm.
BMP	Does the application method integrate with other BMP procedures to reduce overall farm risk?
Meteorological	Use of methods that are unsuited to the prevailing weather conditions and/or application window increase the risk of incidents.

The selection of application method and equipment varies considerably but should always be based on the 'best option' for efficacy and efficiency whilst meeting BMP objectives. Refer to Section 7 for more details on equipment and application methods.



## 3.6 Meteorological conditions

Weather conditions are not only a primary determinant of efficacy, they determine whether the spraying operation should proceed, be delayed or aborted .

### Hazards - Meteorological conditions

Rainfall	Reduced efficacy or off-target movement of pesticides.
Wind speed	How far will the pesticide travel due to wind?
Wind direction	What direction will the droplets move after release?
Temperature	High temperatures increase the risk of pesticide movement, reduced efficacy, volatilisation and evaporation.
Relative humidity	Lower relative humidity decreases droplet survival times.
Turbulence	Determines the way that droplets disperse over a crop.
Droplet sizes	Smaller droplets are carried further by wind, and evaporate faster than larger droplets.
Specific conditions	Surface temperature inversions, thermal activity, gusty winds.
Changes	Changing weather conditions before, during or after spray applications.

### 1. Determine weather conditions

- Use weather equipment that has been accurately calibrated and well maintained.  
Automatic weather stations provide accurate records that can be used to examine conditions leading up to, during, and after spray application. Examination of longer term records will often assist to determine optimal times to schedule sprays, and possible reasons for less effective applications. Many automatic weather stations have data storage capabilities, so that historical data can be downloaded or reviewed. This may be important when making spray decisions and/or for analysis in the event of an investigation.
- Hand held equipment can be used to monitor key climate parameters (e.g. wind speed and direction, temperatures, relative humidity) at a location at a particular time.
- Readings from meteorological equipment must be taken as close as possible to the actual application site and at the time of application. That is, the recorded weather data must be relevant to the conditions in the field where pesticides were applied. If the application is distant from the weather station, consideration should be given to the use of hand-held equipment near the application site as a cross-check. This will be important if investigation of a spray application is required.

### Use the Bureau of Meteorology (BOM) information system

#### a) Weather by Fax

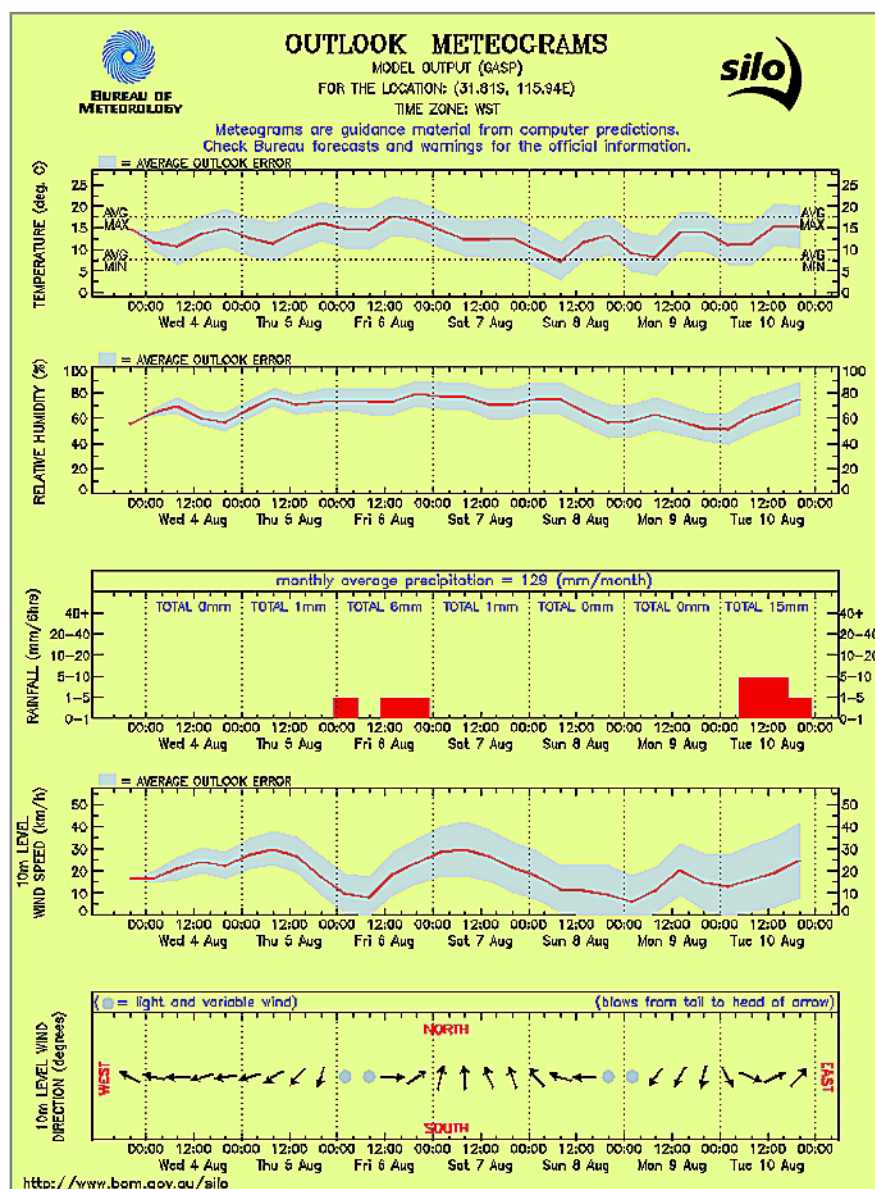
- Any person with access to a fax machine can call the Weather by Fax access lines to receive up-to date satellite images, synoptic charts and forecasts. The telephone numbers to access this service are listed in local telephone directories under 'Bureau of Meteorology' and on the Bureau of Meteorology website ([www.bom.gov.au](http://www.bom.gov.au)).



## b) Outlook Meteograms

Outlook meteograms provide ‘best estimates’ (based on BOM computer models) for future temperature, relative humidity, rainfall, wind speed and wind direction in a particular area. These should always be used in conjunction with weather forecasts which include meteorologists’ experience and interpretation. Meteograms can be viewed as composite summaries as shown in Figure 3.1, to provide an overview of each parameter (e.g. wind direction) can be examined in more detail. The service also provides for varying time frames and precision. The 7 day predictions (Fig. 3.1) provide a good general picture of the weather over the next week, but the detailed meteograms (See Appendix 5), which extend to 3 days, should be used for specific spray decisions. This service is not only valuable for spray decisions but may also be used during picking. The service is by subscription and more information can be obtained from the BOM web site, under the SILO (Services for Agriculture) section.

Fig. 3.1. Example of an Outlook Meteogram.



Source: Bureau of Meteorology



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## 2. Assess likely changes in the weather

- What were the meteorological conditions leading up to the spray?
- Is significant rainfall likely in the 48 hours before and after a spray?
- What effects will rainfall after application have on effectiveness and potential environmental impacts?
- Are the conditions likely to deteriorate or alter significantly during the application?

BOM Outlook Meteograms or similar services may be used to assess likely weather changes.

## 3. Monitor wind

- Monitor wind conditions before, during and after the application of agricultural pesticides near sensitive areas. **The use of smoke will help identify the presence of a surface temperature inversion layer, thermal activity or instability.**
- Aircraft applying pesticides to cotton should be fitted with smoke generators, so that the pilot can check changing conditions over the crop.
- Generating smoke from a ground source will assist all applicators to monitor wind conditions. One method of generating smoke is to thoroughly wet a bale of hay, let it drain, then use a small amount of diesel to set fire to it. The smoke is white which makes it highly visible under all conditions, and the smoke plume can be illuminated by lights for night applications.
- Install windsocks that are sensitive to winds as low as 2-4 km/hr at strategic locations. These must be well clear of local obstructions that may influence wind direction, and must be clearly visible to applicators during the spray operation. Local pesticide suppliers often supply windsocks free of charge as part of their commitment to BMP.
- Use weather stations close to the application area and/or hand held equipment to monitor and record conditions prior to, during and after the application.
- Follow Stop-Go-Delay guidelines that were established as part of the PAMP for each field.

## 4. Communicate

- Keep operators and applicators informed of weather conditions before, during and after the application.
- The operator has difficulty detecting weather changes from the cab or cockpit, and relies on the grower to inform him of changes that may affect efficacy or increase risk. The operator should also be warned of potential hazards that occur after spraying has started (e.g. a chipping gang arrives unannounced).
- If conditions deteriorate so that risk of drift and/or off target contamination increases, then Stop-Go-Delay decisions must be made. Keep all personnel informed of decisions at the time.

## 5. Be decisive

If the weather conditions become hazardous, implement PAMP procedures to delay or abort the application.



### 3.6.1 Air movement

Spraying should only be undertaken when the direction and strength of the airflow is assured. The grower should be satisfied that pesticide will not be moved off target, or endanger the spray operator (e.g. strong gusts or low / variable wind conditions).

#### **Hazards - Air movement:**

- Wind speed - How far pesticides may be carried.
- Wind direction - Where pesticide droplets or residues may be deposited.
- Turbulence - Predictability of droplet movement.
- Droplet sizes - Smaller droplets are carried further by wind than larger heavier droplets.
- Evaporation - Dry wind increases evaporation rates which, in turn, affects droplet survival.

#### **Air movement and spraying**

Wind speed, horizontal and vertical air movement around cotton paddocks can be used to understand the droplet transport process. When droplets are large (e.g.  $> 250 \mu\text{m}$ ) their passage towards the ground from a sprayer is largely influenced by gravitational forces, but largely unaffected by air currents, unless there are high wind speeds. (Refer to Section 7).

However, many droplets produced by aircraft, boom sprayers and air assisted sprayers are smaller than  $250 \mu\text{m}$ . As droplet size decreases, their movement becomes increasingly controlled by the movement of air around them.

Consequently it is important to understand air movement in and around each field in order to spray effectively and manage spray drift.

#### **Wind speed**

- Spraying under calm (still) conditions, surface temperature inversions or strong thermal activity can be hazardous. If the wind strength and direction are unknown, the movement fate of a spray product cannot be determined with confidence.
- Avoid spraying under variable or low wind speed situations ( $< 3 \text{ km/hr}$  or  $0.83 \text{ m/sec}$ ). In these conditions, small wind gusts can change in wind direction and can carry fine particles considerable distances, and it is impossible to predict where they will land. A wind that is 'on the change' or swinging wildly can lead to striping and uncontrolled off-target deposition of pesticide.
- Stop or delay spraying in strong and/or gusty winds greater than  $15 \text{ km/hr}$  ( $4.2 \text{ m/sec}$ ).
- Follow established PAMP procedures.
- Do not rely on buffers alone if the wind is blowing towards sensitive areas.
- Use windsocks and smoke generators as indicators of wind speed and direction.

Weather stations on the farm must be able to measure wind direction and speed accurately, and to store data. It is preferable to have adequate data storage capacity in the station to store up to 60 days of data within the unit and/or via a direct link to an external storage (e.g. a computer) so that longer term trends can be examined.



Hand-held wind speed meters with acceptable accuracy are available from a number of distributors. Cotton Australia can assist with the names of weather monitoring equipment and suppliers in your area.

As a guide to estimating wind speed, Table 3.2 illustrates part of the Beaufort Scale of Wind Speeds. Pesticide spraying should cease when at Beaufort No. 0 or greater than No. 3.

**Table 3.2. Section of the Beaufort Scale of wind speed.**

Beaufort No.	Windspeed			Description	Notes
	Km/hr (KPH)	m/sec	Knots		
<b>0</b>	<b>&lt; 1</b>	<b>&lt; 0.3</b>	<b>&lt; 0.54</b>	<b>Calm</b>	<b>Smoke rises vertically (avoid spraying)</b>
<b>1</b>	<b>1 to 5</b>	<b>0.3 - 1.4</b>	<b>0.5 - 2.7</b>	<b>Light air</b>	<b>Direction of wind shown by smoke but not by wind vanes.</b>
<b>2</b>	<b>6 to 11</b>	<b>1.7 - 3.1</b>	<b>3.2 - 5.9</b>	<b>Slight breeze</b>	<b>Wind felt on face; leaves rustle; ordinary vane moved.</b>
<b>3</b>	<b>12 to 20</b>	<b>3.3 - 5.6</b>	<b>6.5 - 10.8</b>	<b>Gentle breeze</b>	<b>Leaves and small twigs is constant motion, wind extends a light flag.</b>
<b>4</b>	<b>21 to 28</b>	<b>5.8 - 7.8</b>	<b>11.3 - 15.1</b>	<b>Moderate breeze</b>	<b>Wind raises dust and loose paper; small branches moved.</b>

### Horizontal wind speed and direction

Differential heating of the ground and sea by the sun causes air masses of varying temperature, humidity and pressure to develop. Air pressure gradients are established which cause air to flow from high to low pressure areas.

Except near the equator, forces due to the curvature and rotation of the earth cause the air in the Southern Hemisphere to flow anticlockwise around high-pressure areas (anticyclones) and clockwise around low-pressure areas. It is this flow of air (on the large synoptic scale) that we experience as wind.

The wind speed and direction above a crop control the direction of spray after release (and its movement towards or away from the target area), and the degree to which droplets are caught by the foliage or pest and the uniformity of deposit.

Sensitive areas and potentially hazardous wind directions should be identified in the property PAMP on a field-by-field basis. Additional precautions need to be taken when the wind direction is towards sensitive areas. If the wind direction and strength are such that they pose a risk of contamination or unacceptable drift or odour, then the spraying should be delayed or alternatives investigated.



## Vertical air movement (stability)

As well as horizontal air movement, the vertical displacement of air has to be taken into account whilst spraying, because droplets can be transported vertically as well as horizontally.

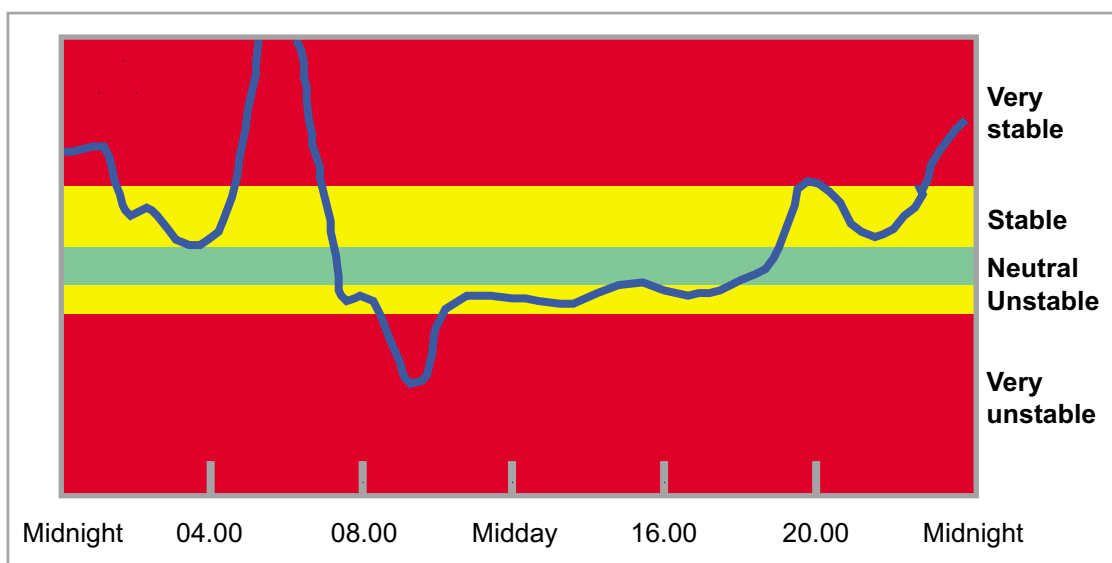
A parcel of air displaced upwards from the ground (i.e. by convective thermal effects) will normally move into a region of lower pressure and expand. This expansion is normally adiabatic (i.e. there is no exchange of heat with the surrounding air) and results in the cooling of the air parcel. The rate of cooling is about 10°C per 1000m.

In summer during the late morning and afternoon, air parcels generated in this way tend to rise and remain hot and are thus lighter than the surrounding air. This air is **unstable** and is characterised (provided there is sufficient moisture in the atmosphere) by the formation of large cumulus clouds. Thunderstorms usually develop in strongly unstable atmospheric conditions. Do not spray if strong upward thermal conditions exist.

Figure 3.3 shows an example diagram derived from actual data of the stability of conditions above a cotton paddock over a 24 hr period. The graph shows clearly that stability varies considerably according to the time of day. The red sections indicate where spraying is not recommended due to the risk of off-target droplet movement. The neutral (green) line shows the optimal times for spraying and caution should be exercised at all other times (yellow).

**Note:** Figure 3.3 is an example only - conditions will vary and should be monitored locally.

Figure 3.3. Example diagram of daily stability of conditions over a cotton paddock



Source: C-PAS

## Turbulence

Turbulence can develop over a crop as a result of the thermal (upward) movement of warm air or the mechanical movement of wind across the ground. A wind or breeze travelling close to the surface of the earth rarely has a smooth flow. The lower air layers move slower than the upper layers because their energy is lost at the earth's surface. Wind speed usually increases with height (close to the earth's surface). Under these conditions, the atmosphere is characterised by the turbulent motion of air produced in part by the movement of air layers against each other and by frictional losses of energy at the earth's surface. The extent of this turbulence is also determined by the 'roughness' of the surface.



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For example, a stand of trees or tall crop would generate greater turbulence for a given wind speed than an area of mown grass.

### Local wind effects

Although primary wind directions and wind speeds are caused by large-scale synoptic systems, small-scale local winds can be generated which can have a significant impact on spraying.

Some examples are given below:

- (a) *Thermal movement of air:* In large open areas under conditions of high radiation, unequal heating of the ground can occur, resulting in the upward motion of large air parcels. As these air parcels rise, air at ground level flows in to replace them. Under such conditions, large-scale circulation currents may form, resulting in local wind flows and turbulence. Residual heat in the ground may cause upward air movement in the evenings or nights. On a small scale, differences in temperature between cultivated and fallow (bare soil) areas can also give rise to local air currents around and within a crop canopy.
- (b) *Thunderstorms:* Thunderstorms can produce strong winds in all directions about a storm cell. Although storms generally track West to East across the Eastern States with the passage of frontal systems (in the south), local wind directions can be highly variable.
- (c) *Katabatic winds:* In hill country or on flat land close to slopes, farming areas can be subject to evening katabatic winds. As land cools, air immediately above the surface can be cooled resulting in that air becoming denser and thus heavier than surrounding air. If cooling occurs on sloping ground, heavy air can flow under gravity to lower levels, resulting in local wind flows.

### Temperature inversions

Stable conditions usually occur at night when the land loses heat by radiation and cools more rapidly than the air above it. As a result the air temperature increases with height (rather than decreasing) and an inversion layer of air forms. This can inhibit vertical air movement and minimise atmospheric turbulence, and is called a **surface temperature inversion**. ‘Blankets’ of fog or smoke indicate such conditions, and fine droplets may become trapped above such layers, and this may contribute to spray drift.

Surface temperature inversions most commonly occur during clear nights that follow hot, sunny days. Surface temperature inversions are often associated with fog or early morning mist, and may persist well after dawn until the ground warms up sufficiently and the air is mixed again.

**Do not spray under *surface temperature inversion* conditions.**



### 3.6.2 Temperature





#### Hazards - Temperature

High temperature	Droplet evaporation, volatilisation, upwards movement.
Temp. differences	Inversion layers, instability, wind generation.
Pesticide	Formulation efficacy, droplet survival.
Safety	Flammability, operator exposure and fatigue.

High temperatures can have a two-fold affect on drift - volatilisation and evaporation.

1. Higher temperatures may increase volatilisation and the resultant vapour may be subject to drift. Higher ground temperatures may also establish air currents that move fine spray droplet vapours.
2. The high temperatures can evaporate the water in the droplets, resulting in finer droplets, and/or particles of pesticide which may drift. The amount of evaporation is a function of temperature and relative humidity so both must be monitored.

Figure 3.4. General indicators for spray decisions.

Smoke	Condition	Notes	Spray ?
	NEUTRAL (e.g. morning)	Cool breeze (4 -15 km/hr). Optimum spray conditions.	✓
	UNSTABLE (e.g. afternoon)	Hot. Low windspeed, thermal activity Risk of upward movement of fine droplets.	✗
	INVERSION (e.g. night)	Low windspeed. Hot during day. Risk of significant off-target deposition of fine droplets.	✗
	STABLE (e.g. dusk)	Low windspeed. Risk of off-target spray deposition.	✗

Source: C-PAS



In general, spray when temperatures are low (i.e. less than 28°C) and the relative humidity is high, (i.e. greater than 45%). Water (the most commonly used spray carrier) evaporates at normal working temperatures. Therefore significant reductions in droplet size may occur after droplets have left a spray nozzle. This problem is particularly acute for small droplets for the following reasons:

#### **Droplet surface area to volume ratio.**

As the size of a droplet decreases, there is a very rapid increase in the ratio between the surface area of a droplet and its volume. In other words, a greater proportion of the surface area of the droplet is exposed to the atmosphere as the droplet size decreases. Hence smaller droplets evaporate faster.

#### **Droplet fall rate.**

As a droplet becomes smaller through evaporation, its rate of fall towards the ground becomes slower (Refer to Section 7). Hence the droplet remains airborne longer, and is more susceptible to further evaporation as it becomes smaller.

#### **The rate of evaporation of a droplet is related to its size.**

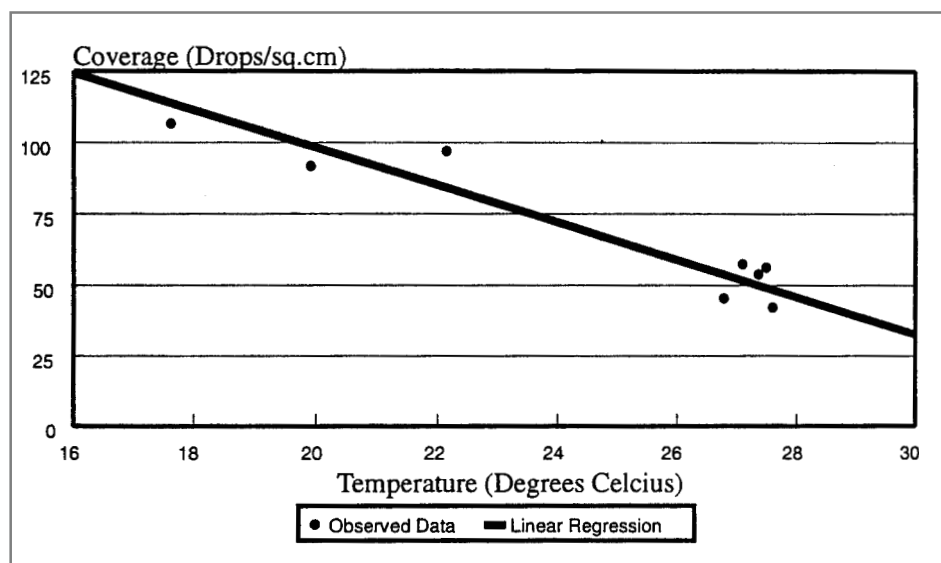
In general, water droplets smaller than 150 µm evaporate 27% faster than droplets larger than this size. This is due to a change in airflow around droplets smaller than 150µm. Larger droplets cause the airflow to be separated from the base of a droplet and no evaporation occurs from this region. In smaller droplets, the airflow contacts most of the droplet and evaporation occurs from the whole surface.

Research to determine the lifetime of droplets (and thus the theoretical distance they will fall under the influence of gravity before all the water has evaporated) has shown that evaporation increases as the temperature increases and the air becomes drier (relative humidity decreases).

When pesticide sprays are applied under typical Australian summer conditions (e.g. 28°C, RH <45%), calculations show that 100 µm droplets will survive less than 12 seconds and 50µm droplets less than 3 seconds.

Figure 3.5 shows the number of droplets on leaves (per sq.cm) of a water based insecticide formulation deposited on a cotton canopy at different temperatures during a field trial. Fewer droplets

**Figure 3.5. Number of droplets per sq. cm deposited on leaves at different temperatures.**



Source: C-PAS



were recovered at the higher temperatures, because droplets evaporated before reaching the target.

Many of the insecticides applied using aircraft are formulated in solvents that have a relatively low volatility. Applied neat without the addition of water, these ultra low volume (ULV) pesticides attempt to overcome the impact of evaporation by using mineral and/or vegetable oil carriers.

### 3.6.3 Relative humidity (RH)

The term relative humidity is used to describe the ‘dryness’ of the atmosphere. It defines the ratio of the amount of water that is contained in a sample of air to that amount which could be contained in the same volume of air if saturated (with water) at that temperature.

It is preferable to spray under high humidity. This is particularly important when water is the carrier, because low humidities are often associated with high temperatures and thus, high rates of evaporation. In general, avoid spraying when relative humidities drop below about 45% at the application site. In irrigated crops, the relative humidity in and near the crop may be higher than the surrounding areas.

Because it is a relative measure dependent upon temperature, the RH increases as the temperature drops and decreases as the temperature increases. It is usual to find therefore, that over a cotton canopy, maximum RH values are recorded at dawn.

**Delta T ( $\Delta T$ ) is the difference between wet bulb and dry bulb temperatures. Avoid spraying at higher temperatures when  $\Delta T$  is greater than  $10^\circ$ .**

The relative humidity and/or Delta T ( $\Delta T$ ) are easily measured in the field using handheld electronic RH meters or whirling psychrometers.

**Figure 3.6 Guide to temperature and relative humidity ranges for pesticide application.**

RH (%)	Temperature ( $^\circ\text{C}$ )								
	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0
100	Application is not recommended due to the risk of rainfall and loss of pesticide.								
90									
80									
70									
60									
50									
40									
30									
20									
10									

Note: This is guide only. All weather parameters and spraying operations must be monitored during spray operations, and BMP (PAMP) guidelines followed.

Source: QDPI

### 3.6.4 Rainfall

Rainfall should be monitored on a regular basis. It is preferable to have an automatic station that can measure intensity and timing of rainfall as well as the daily totals.



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Longer term rainfall trends and predictions should also be monitored by using the Bureau of Meteorology or similar services.

Some pesticides (e.g. endosulfan) have specific label restrictions referring to weather conditions during application.

### **Hazards - Rainfall**

Rain wash	Pesticides may be washed off the plants and into waterways.
Soil movement	Soil containing pesticide may be moved off the field.
Contamination	If there is water standing in the field it may be contaminated and carry the pesticide into the soil or into waterways.
Indirect effects	Are the fields boggy and likely to cause problems with groundrigs?
Efficacy	Has the application been diluted or washed off the plant? Will a respray affect re-entry periods?

Rainfall in the 48 hours prior to pesticide applications should be monitored and recorded.

The following points should be considered (after rain) when planning an application:

- Will the rainfall enhance or reduce the efficacy of the pesticide?
- Are fields likely to be boggy and will crop/soil damage occur if a ground rig is used?
- Is the ground rig likely to become bogged, unstable or roll over in the conditions, and what risk is the pesticide load likely to pose?
- Has the rain affected the pest levels and is there a need to spray immediately (based on new insect checks)?
- Are the tailwater catchment areas and dams full?
- Has there been significant runoff to neighbouring properties, and was there any soil transportation?

If there is measurable rainfall during an application, efficacy of the pesticide may be reduced, or the pesticide may be carried off-target by runoff. In addition, if there are storms these may be accompanied by strong, gusty or unpredictable winds. Spraying should stop if there is risk of off-target movement, reduced efficacy and/or danger to applicators.

Similarly, rainfall in the 48 hours after pesticide application should be monitored and recorded. The following points should be considered if rainfall occurs after an application:

- What was the amount and intensity of the rainfall, and is there likely to be more?
- What type of pesticide was used (e.g. rainfastness, formulation), and has the efficacy been affected?
- What was the pesticide that was applied and what are the risks if the rainfall has washed it off-target? If the pesticide was a herbicide - has it been leached or moved in the soil profile?
- If there was runoff, was this captured in tailwater and other storage? Was there any discharge into waterways (e.g. rivers)?



- What action is necessary to check the effects of the rainfall? Is remedial action required?

### 3.7 Drift

Efficient pesticide application minimises the off-target movement of the pesticide whilst still maintaining an acceptable level of pest management. Significant off-target movement of pesticides should not occur if the correct application techniques are employed under favourable environmental conditions.

#### Types of spray drift

Two types of drift may occur, namely droplet/particle drift and vapour drift. A combination of the two types may also occur.

#### Hazards - Drift

Crop & other damage	Damage to non-target crops or enterprises (e.g. fish farms).
Contamination	Persons, places, waterways or environments.
Odour	Unpleasant odour contamination of residential and non-target areas.
Reduced efficacy	Pesticide that has drifted has not reached the intended target.
Litigation	Off-target movement of pesticides may result in litigation.
Legislation	Off-target movement of pesticides may result in restrictions being placed on the use of specific pesticides.

Droplet (or particle) drift is the most common, with three types occurring:

- Direct wind drift
- Thermal drift
- Inversion drift

Small droplet size plays a role in all instances (See Section 7).

Vapour drift is the movement of volatile components of pesticide in air currents during and/or following application. These are significant where the volatile component has biological activity (e.g. 2,4-D ester). This is why there are special restrictions on this pesticide in mixed-cropping areas, and in specialized regions within States (e.g. 'hazardous areas' as defined in the Queensland Agricultural Chemicals Distribution Control Act).

#### Reducing spray drift

Growers and applicators need to be aware of the major factors that contribute to drift. These are:

- Droplet size. This is determined by the application method, equipment and adjuvants in the pesticide mixture used. The use of drift reduction nozzle designs or larger orifice nozzles at low pressure may reduce drift danger.



- Weather conditions during and immediately after application.
- Height and distance. The greater the height and distance from the target plant at which pesticides are discharged, the greater is the risk of drift.

The nozzles that are selected, droplet size and equipment set-up should aim to minimise drift, but must still apply the pesticide efficiently so that the target pest is controlled. The use of well designed spray shields on ground rigs will reduce drift. Refer to Section 7.7 for more information on shielded sprayers.

## 3.8 Buffers

Buffer zones are used to collect spray droplets that may otherwise drift onto sensitive areas, but they should only be considered as the last line of defence.

**Use of buffer zones on farms is now a requirement for the use of some pesticides - Read the label before use.**

There are three types of buffer zones that can be used alone or in combination:

<b>Offset buffer</b>	A portion of the target crop is left untreated on the downwind side. This untreated section is sprayed once the weather conditions become more favourable, the application setup can be adapted, or a less hazardous product can be used in the offset buffer zone.
<b>Vegetative buffer</b>	<p>This is an area between the edge of the crop being treated and a sensitive area. It may consist of non-sensitive fields, natural vegetation, fallow areas or specially planted buffer vegetation. Well-planned vegetative buffers provide barriers for noise, wind and dust, are aesthetically pleasing, and provide wildlife habitats.</p> <p>The development of effective vegetative buffers is a long term process that should be incorporated into the PAMP.</p> <p>Refer to: “Growing Trees on Cotton Farms” published by the Rural Industries Research and Development Corporation (1999) and Section 1 of this handbook.</p>
<b>Crop buffer</b>	These are strategically planted crops that should require fewer pesticide applications during the season. They may include transgenic cotton, maize or other crops that attract the same insects as cotton.

Factors to consider when planning buffer zones:

- Features of the sensitive area,
- Properties of the pesticide(s) being used,



- Distances between the crop and sensitive areas,
- Efficiency of the buffer zone in capturing droplets,
- Methods of application,
- Weather conditions, critical wind directions and speeds.

Vegetative buffer zones should be established on the downwind side to intercept drift, but additional vegetative barriers can be established strategically throughout the farm. These not only assist with drift minimisation, but improve the property and provide additional windbreaks. When designing a vegetative buffer, the main objective is to maximise the catching surface for spray droplets. Plants that have thin needle like foliage and many small branches such as River She-Oak (*Casuarina spp.*) are the most suitable. The species that is selected must be suited to the area to ensure survivability. The vegetative barrier should allow about 50% of the wind flow to pass through it. Several lines of vegetation are better than one line of more dense vegetation. The buffer should be approximately 8 metres high when mature, and consist of a complex of low shrubs and medium height trees which form a vegetative barrier from the ground upwards.

When planting vegetative buffers, consideration should be given to aerial and groundrig operators so that the trees and vegetation do not pose a significant risk to the applicators. If possible, discuss the planting of vegetation buffer zones with your contract applicators. Also, planting buffers right up to the boundaries of sensitive areas may increase the risk of off-target pesticide contamination. Consider crop buffers or other alternatives to provide an untreated zone.

## 3.9 Observing spray applications

It is a responsibility of the grower (or their appointed representative) to observe spray applications, ensure that PAMP guidelines are followed, that the pesticide is applied correctly and that the application details are recorded.

### 3.9.1 During the spray

#### Hazards - Spraying

Meteorological	Changes that may increase drift and/or operational hazards.
Equipment	Malfunction may result in incorrect application or spillages.
Accidents	Chemical exposure, physical injury, environmental damage.
Handling	Chemical handling, mixing and loading increase risk of contamination.
Personnel	Unauthorised entry into the spray zone.
Unforeseen	Changes in the awareness zone (e.g. a vehicle enters the area).

When observing spray applications, remember:-

- The operator may not be able to accurately assess the prevailing conditions (and changes) from the machine cabin or aircraft cockpit.
- The operator may not be aware of new hazards (e.g. newly built power lines or house).



- To assist in monitoring the surrounding areas (e.g. to observe whether cotton chippers arrive unannounced).
- To assist in monitoring the application equipment (e.g. malfunctioning nozzles, flat tyres, leaks, loose aircraft booms).
- Communicate with the operator frequently with updates and exchanges of information.
- Don't hesitate if there is a problem - take positive action!

Monitor weather conditions near the application site using hand held equipment and check these readings against automatic stations in the vicinity.

## Ground spraying

- If a contractor is being used, he should demonstrate that he has an Operators Licence (Queensland only).
- The grower appointed representative should supervise all applications.
- Boom height should be as low as possible, consistent with nozzle specifications and coverage requirements. Use of wide angle (110°) and low drift nozzles will assist in reducing drift in groundrig applications.
- Vertical movement of the spray boom should not exceed 0.5m.
- Observe any drift. Viewing the application with the sun behind the applicator will assist in highlighting drift.
- Nozzle selection, configuration and pressures should be optimised to produce the desired droplet size and minimize drift.
- Ground spray units should dispose of unwanted pesticide in the correct manner. The unit should be decontaminated before moving to another farm.
- Communicate with the operator and confirm completion.

## Aerial spraying

- Pilots and operators should be accredited by the Aerial Agricultural Association of Australia (AAAA).
- The grower appointed representative should supervise the application.
- Insist on aircraft fitted with DGPS equipment. Use of human markers is discouraged due to the danger of personal contamination. Observers and their vehicles often assist to provide reference points for the pilot (eg. during night spraying).
- Aircraft should be fitted with smoker devices so that the pilot can release smoke at regular intervals, particularly when near sensitive boundaries and if a change is reported.
- Ensure that the aircraft is straight and level when over the crop.
- Aircraft wheel height should be 1 - 2m above the crop canopy during application.
- Observe any drift. Viewing the application with the sun behind the applicator will assist in highlighting drift. Large droplet placement (LDP) should be used if applicable.
- Wherever possible request that the pilot turns over nonsensitive areas.
- Monitor switch on and cut off points for each run, including clean-up runs.
- Communicate with the operator and confirm completion.



Monitor and record the weather conditions throughout the application. Even if you have an automatic station, check the conditions at a position near the field being sprayed using handheld equipment. Ensure that windsocks are functioning properly and that smoke is used if required.

### 3.9.2 STOP / GO Guidelines

Each application must be observed with due consideration to PAMP procedures and circumstances which may arise during the application. However, there are some key guidelines that apply to the majority of pesticide applications.

**Note: Table 3.7 is a guide only - Always monitor the conditions at the time of application.**

Refer to the nozzle selection and equipment setup guidelines in Section 7 and manufacturers handbooks for specific operating guidelines.

**Table 3.7. General guide to suitable temperature, wind and relative humidity conditions for spraying.**

Temp (° C)	Wind		Relative Humidity (%)								
	km/hr	(m/s)	20	30	40	50	60	70	80	90	100
15 - 20	<3	<0.83									
	3 - 15	0.8 - 4.2									
	15 - 20	4.2 - 5.6									
	20 +	5.6 +									
20 - 25	<3	<0.83									
	3 - 15	0.8 - 4.2									
	15 - 20	4.2 - 5.6									
	20 +	5.6 +									
25 - 30	<3	<0.83									
	3 - 15	0.8 - 4.2									
	15 - 20	4.2 - 5.6									
	20 +	5.6 +									

Source: 4T

### 3.9.3 Delayed sprays

If conditions change and the spray operation is stopped, decisions will have to be made as to whether to delay or abort that particular spray.

Examples of why an application may be delayed or aborted are:

- Rain, storms, high temperatures or other adverse weather conditions,
- Forecasts indicate that adverse weather (e.g. severe thunderstorms are imminent),
- Operating problems such as leaking equipment,



- Complaints from neighbours,
- Accident (e.g. if the ground rig damages the spray boom on a fence post),
- Unauthorised persons and/or vehicles have entered the spray zone,
- A decision is made to change pesticide and/or equipment selection.

In all instances, personnel involved in the application (including the agronomist/consultant) should be advised. Decisions must then be made with due consideration to:

- Whether the application is delayed or aborted,
- What effects a delay will have on the spray mixture - how long until it is unusable?
- What to do with any unused spray mix (according to PAMP),
- What is the provisional plan for the application - what pesticides, application method and timing,
- Are field checks necessary before a revised strategy is established?
- If the delay is due to an accident, what remedial action (if any) is required?

### 3.9.4 Complaints

Ensure that complaint handling procedures are clearly outlined in the property PAMP, and that they are followed in the event of a complaint being received.

During application

- Verify that it is a genuine complaint (i.e. not mischievous or malicious),
- Suspend operation,
- Discuss reason for concern,
- Resume operation if agreement is reached between growers, complainant and applicator,
- Cancel the application if no agreement can be reached,
- If agreement cannot be reached, an independent party should be contacted to mediate and assist in resolving issues/conflicts.

After application

- The grower should discuss the matter with the complainant and the operator.
- If the complaint is received by the operator, they should discuss the matter with the grower.
- Complaints received by the Environmental Protection Agency (EPA), NSW WorkCover Authority or Department of Education, Training and Industrial Relations (DETIR) - Workplace, Health and Safety (Qld).

These agencies will investigate complaints and may request additional information or records from the grower and/or applicator. Complaints will be referred to the grower and operator for resolution.



Appropriate authorities to be notified of any unresolved complaints:

Cotton Australia.

Cotton Growers Association.

Local Chemical Liaison Committee.

Environmental Protection Agency (if environmental issues are involved).

Dept. of Education, Training and Industrial Relations (DETIR) - Workplace Health and Safety (Qld) or NSW WorkCover Authority.

### 3.9.5 Accidents

Accident and emergency procedures should be included in the property PAMP plan. Be prepared for the worst case scenario, and ensure that first aid and spill equipment are maintained properly.

In the event of an accident during spraying:

- **Attend to personnel involved in the accident as highest priority.**
- Assess the situation quickly and request assistance from all relevant personnel.
- Implement emergency procedures and contact Emergency Services (if required).
- Keep all non-essential personnel and onlookers away from the accident scene.
- Implement fire and spill control procedures if required.
- Secure the area and make equipment safe if possible.
- Assist Emergency Services personnel when they arrive.

Once the emergency has passed, make detailed notes of the accident with input from personnel who were involved. These notes will help investigators and will assist in modifying PAMP procedures in the future.

Review the accident reports and provide a summary (including revised procedures) to all relevant personnel. Refer to Section 6 for more information on pesticide spills, clean-up and disposal procedures.

### 3.10 Post spray

Confirm completion of the spray application with the operator and complete all application records. If an automatic weather station is used, it is useful to print out the weather conditions during the spray application and attach the printout to the spray record. Examples of spray records are shown in Section 4.

Once a spray application has been completed, it is important that weather conditions are monitored for at least 48 hours afterwards. Heavy rainfall may wash pesticide off foliage or into watercourses, and high temperatures may volatilise pesticide residues causing off-target movement and odours. Losses may also result in reduced pesticide efficacy.



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## 3.11 Cleaning equipment

After each spray application, equipment should be cleaned thoroughly. Any unused spray mix should be disposed of correctly.

Refer to Section 6 for pesticide disposal methods, and Section 7 for cleaning and decontamination procedures.

## 3.12 Community liaison

Community liaison plays an important role in the BMP process.

Active participation in this process often reduces misconceptions, misinformation and ultimately misunderstandings. Genuine community concerns should be addressed via Cotton Australia and the Cotton Growers Associations.



## 4. Record keeping

Record keeping is an essential part of management, and records should be stored in such a way that all related records can be retrieved efficiently. Computer software programs (e.g. CottonLogic®) make recording and retrieval of the large number of records more manageable.

### Points to remember about record keeping:

- Develop a system that suits your farm circumstances.
- Keep accurate records in a proper filing system.
- Add notes where specific records or data are not adequate.
- Make use of the records to examine spray efficiency and achievement of BMP.
- Retain records for 3 years.
- Records are essential to resolve disputes or settle litigation.
- Records may be required by some pesticide labels or as part of general legal requirements under specific State Government legislation.

### 4.1 Spray records

Accurate records of pesticide applications are essential, not only as a management tool, but to provide an historical record of spray activities.

Details of each pesticide application and the prevailing weather conditions (including before and after application) should be recorded as soon as possible after completion of the operation. Any additional data and incidents should be recorded and attached to the spray record for reference and action (if required).

Spray records should contain the following information:

- Date and times of application (including start, refilling and finish times),
- Persons authorising and supervising the application,
- Details of property owner, appointed representative and contact numbers,
- Property, field, crop and area (hectares) details,
- Pest details (or reference to a field check sheet),
- Chemical names, type, application rates, spray/water volumes, batch numbers,
- Applicators name and equipment operators name,
- Method of application, equipment, nozzle types and specific equipment set-up,
- Operating pressures and other relevant information, including any changes that were made during the application,
- Meteorological conditions (including before and after the application),
- Operating conditions and any other observations,
- Compliance with PAMP/BMP guidelines and checks.



## 4.1.1 Spray orders

A written spray order should be completed for each pesticide application request. This is essential when ordering applications from contractors, but should also be done for all on-farm applications. A proper spray order form can provide a lot of information for best management practices, and in the event that there is a spray failure or litigation. An example of a spray order form including notification of completion details is shown in Figure 4.1.

Figure 4.1. Sample Spray Order form.






<b>SPRAY ORDER FORM</b>						
To .....		Tel .....		Fax .....		
Farm/Grower.....		Order date .....		No. 10 6 0 3		
Tel ..... UHF.....		Date / time req'd .....AM PM				
Crop ..... Map ..... Y N		School bus times .....				
BMP No: ..... PAMP .... Y N		Check sheet reference .....				
Neighbours notified ..... Y N		Chem. supplier .....				
Consent to waive DNSZ ..... Y N		Person placing order .....				
Field No's	Ha.	Chemical	Rate/ha	App.vol.	Total applied	Endosulfan Sprays to date
Additional information (e.g. band spray widths, specific requirements).....						
.....						
<b>CONFIRMATION of APPLICATION (To be completed by Pesticide Applicator)</b>						
Job No.	Method	Operator	Application date	Chemical used		
Unit No.	Speed kph	Nozzle type	Boom length	Trade name		
Type	PPE (MSDS / Label) Y N	Nozzle/blade angle	Boom % of wingspan	Formulation ULV EC		
GPS fitted? Y N	Closed mixing system Y N	Swath (m)	Boom pressure KPa / psi	Active ingredient (g/ha)		
<b>START</b> Time:	Wind speed & direction	Temperature °C	Humidity %	Conditions Clear Overcast Shower		
<b>FINISH</b> Time:	Wind speed & direction	Temperature °C	Humidity %	Conditions Clear Overcast Shower		
Applicator notes (e.g. job not completed): .....						
.....						



## 4.1.2 Spray records

Once a pesticide application order has been confirmed, a spray record should also be completed at the time of application by the observer to provide a permanent record of the conditions before, during and after spraying. Commercial operators are required by law to keep records of all spraying operations and it is a recommended procedure for all users of agricultural chemicals. Complete records can provide good evidence of such operations should a dispute arise. An example of this record is shown in Figure 4.2.

Figure 4.2. Example of a Spray Application Record.

Date		Spray Order N°		001698	
Grower Address				Mud Map	
Field					
Crop					
Area					
Operator					
Accreditation		Commercial Operator <input type="checkbox"/> Chemcert <input type="checkbox"/> Other <input type="checkbox"/>			
Neighbours Notified		Yes <input type="checkbox"/> Label Conditions		Followed <input type="checkbox"/>	
Operator Protection		AC Cab <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>			
Chemical \ Adjuvants		Rate	Batch	Total L	Sprayer
					Water Volume
					Nozzle Details & Configuration
Pests					Pressure
					Speed
Spraying Conditions					
Time	Wind Speed m/s \ kph	Wind Direction	Temperature °C	Humidity %	Time
Notes					
This is a true and accurate record of the application. Signed:					
To satisfy specific situations, National or State legislation may require that this record be supplemented with further information. Refer to product label specifications.					

## 4.2 BMP records

In addition to spray application details, written records should be kept of the following:

- Meetings conducted as part of the BMP/PAMP process.
- Personnel training, refresher courses and accreditation gained.
- Details of equipment checks and calibration.
- Agreed notification arrangements and records of notifications (spray advice notices) during the season.
- Details of delayed or postponed spray applications.
- Records of complaints, accidents, spills and operational errors, and what remedial action was taken.
- Corrections or updates made to the PAMP.

## 4.3 Chemical details

The grower and applicator should keep MSDS and label details of each chemical used or stored on the farm. These can be obtained from the supplier at the time of purchase. MSDS contain important information about each chemical, and should be read and understood before the chemical is transported, stored, mixed or applied.

A register of all chemicals used and stored on the farm should be maintained and supported with monthly stocktakes. Batch numbers and date of manufacture should be recorded for each application so that the chemical can be traced back to the manufacturing site.

Growers should check local statutory requirements regarding chemical registers and stores records. Refer to Section 6 for details of label and MSDS contents.

## 4.4 Using records

The purpose of keeping good records is so that they can be referenced in order to improve methods or to investigate problems. Typical uses for application records include:

- In the event of a suspected spray failure, good spray records may assist in determining why the pesticide was not as effective. Proper records will also help to define the best results and equipment set-up for specific pesticide applications on individual farms.
- These records form the basis for decision making and adherence to the TIMS resistance strategy throughout the season.
- Spray records can be cross-referenced to financial accounts to obtain costs per application and total costs per season.
- Spray records are required as part of the BMP and Ingard® audit processes.
- In the event of a dispute or litigation, complete records are essential to demonstrate that due diligence has been observed.
- Records allow longer-term trends to be examined and compared to yields and pest levels over different seasons.
- Meeting legislative requirements (State and National).



## 5. The target

*Target - the best place to deposit a pesticide to achieve adequate control.*

The target may not be the actual pest (e.g. soil applied herbicides for weed control) or the site where the pest is causing damage (e.g. soil applied granular insecticides for thrips). Most insecticides do not rely on contact with the insect for control to be effective.

**Weeds** Weed control, including the use of herbicides, accounts for up to 10% of the total variable costs of growing cotton (McMillan 1988). Of this, about 5% of total operating costs are herbicides (Boyce 2000).

The strategies adopted for weed control are designed to reduce weed populations below levels that will affect yield and quality, as well as minimising the seed store for subsequent seasons. While thresholds for weeds are not as well defined as they are for insects and mites, the strategies used for herbicidal control of weeds require a thorough knowledge of weed identification, biology, susceptible growth stages, herbicide activity and application methodology. Refer to Table 5.1 and Figure 5.2.

In the early stages of growth, cotton is a poor weed competitor and is vulnerable to a wide range of insect and mite pests at all growth stages. Effective pest management in cotton requires a clear understanding of pest thresholds and the action to be taken when these are reached.

**Insects** Insecticide usage accounts for about 25% to 35% of the total operating costs of growing cotton (Boyce 2000). It is the largest single operating cost, has a significant influence on final yield, but is a cost that can be controlled by good management. Refer to Table 5.1 and Figure 5.2.

About thirty species of insects and mites cause economic damage to cotton in Australia. However, the number of regular, serious economic pests is limited to about five species: two *Helicoverpa* species, mites, aphids and mirids. In most cases, the major pests and their most vulnerable stages for chemical control are well known (Forrester and Wilson 1988). For *Helicoverpa*, aphid and mite control, the guidelines of the Insecticide Resistance Management Strategy should be followed.

To correctly define a target the following factors should be considered:

- Correct pest identification,
- Biology, ecology and behaviour of the pest,
- Crop characteristics,
- Pest threshold levels,
- Pesticide characteristics.

Once the target has been identified, the correct application method can be selected to ensure effective pest management with minimal impact on the environment.

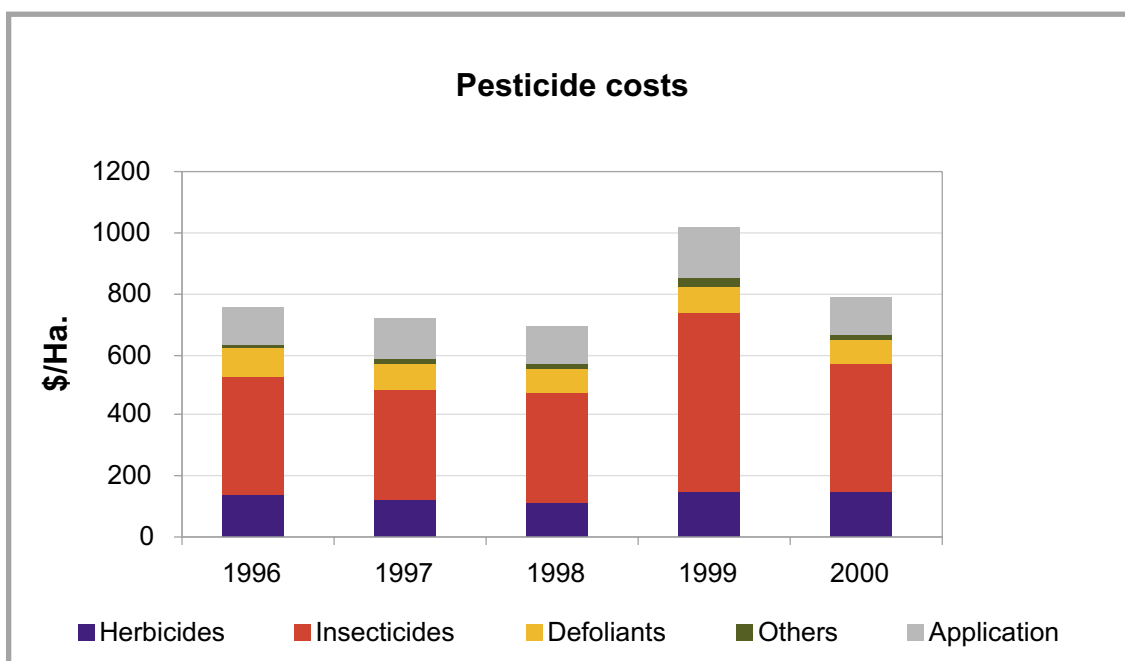


**Table 5.1. Estimates of pesticide costs in cotton, 1996 - 2000.**

\$/Ha	1996	1997	1998	1999	2000
Herbicides	136	121	115	147	151
Insecticides	390	363	358	592	414
Defoliants	94	89	83	88	86
Others	15	15	14	20	15
Application costs	119	126	120	171	122
All pesticides	754	714	690	1018	788
Operating costs	2697	2508	2651	2920	2744
<b>% of operating costs</b>					
Herbicides	5%	5%	4%	5%	6%
Insecticides	14%	14%	14%	20%	15%
All pesticides	28%	28%	26%	35%	29%

Source: Boyce, 2000

**Figure 5.2. Chart of relative pesticide costs in cotton, 1996-2000.**



Source: Boyce, 2000



## 5.1 Target identification

Effective pest management can only be implemented after the pest has been correctly identified. Similar pest species may vary considerably in their sensitivity to particular chemicals. The best example of this in cotton is the difference in susceptibility to insecticides between *Helicoverpa armigera* and *Helicoverpa punctigera*. *H. punctigera* is generally more susceptible to pesticides than *H. armigera*. *H. punctigera* often predominates early in the season, but as the season progresses and *H. armigera* becomes more dominant, different pesticides must be used. Cotton consultants, agronomists and Government personnel can assist growers to correctly identify insect and weed species.

## 5.2 Pest biology, ecology and behaviour

**Biology**      *The morphology, physiology, anatomy, behaviour, origin and distribution of animals and plants.*

**Ecology**      *Organisms' relationships to one another and to their surroundings.*

Understanding the biology and ecology of pests will often identify stages in their life cycle when they are most susceptible to pesticides (and other control measures). In general, pests are most susceptible during the early stages of their life cycle.

The biology of the pest usually determines the type of pesticide, growth stage timing and formulation (e.g. most synthetic pyrethroids are effective on *Helicoverpa spp.*, but not on mite species).

The ecology of the pest often determines the application method, application timing and equipment that are used. A nozzle directly over the row may be required to provide a directed application.

Examples in cotton include:

- Sucking insects often congregate on the growing points of the plant so these must be thoroughly sprayed.
- Mites congregate on the underside of leaves. For a contact insecticide such as Kelthane® to be effective, the spray would have to be directed upwards onto the underside of leaves.
- Abamectin is also registered for use on mites. However, once applied properly, this product is translaminar, so although coverage is still important, it is not as critical to spray the undersides of the leaves as Kelthane®.

Knowledge of the biology and ecology of predator and beneficial species is also an essential part of integrated pest management, and influence what pesticides are used.

## 5.3 Crop characteristics

Crop growth rate can affect pesticide timing, particularly for insecticides that are only active on the plant surface, by reducing the length of effective residual activity through 'growth dilution'.

Crop growth habit such as height, leaf shape (e.g. okra vs normal leaf) and canopy size can affect the set-up of application equipment. Crop growth stage can affect the choice and timing of pesticides, particularly herbicides.



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Many pesticides have specific requirements related to crop stage. For example, many herbicides cannot be used when the cotton crop is young or crop damage will occur. In addition, pesticides may have label restrictions so that they can only be used at specific stages of crop development. For example, endosulfan can only be applied on cotton that is higher than 20cm (aerial) or within Insect Resistance Management Strategy Guidelines.

## 5.4 Pest and damage threshold levels

Pest threshold level	<i>The pest population density at which control measures need to be implemented to prevent economic damage or delayed maturity occurring.</i>
Damage threshold level	<i>The amount of damage that can be tolerated by the crop after which control measures need to be implemented to prevent economic loss.</i>

Pest and damage thresholds are fundamental components of IPM strategies. Pesticide application is not justified until the target has been clearly defined, and it is determined that the pest threshold level has been reached.

Use of thresholds requires accurate, objective sampling to provide reliable estimates of pest or damage levels.

Threshold levels that are applied commercially are set at pest population or damage levels above which economic loss or undesirable consequences, such as maturity delays, will occur if no action is taken (Shaw, 1994). These levels are determined with due consideration to:

- Natural control and mortality of the pest,
- The crop stage and location,
- The capacity of the plant to tolerate damage and/or compensate,
- The role of beneficial insects and control agents,
- Cost - benefit ratio of the application.

Refer to: ENTOPak (published by the Australian Cotton CRC) for details of threshold levels and sampling techniques for cotton.

‘Cotton Pest Management Guide’ which is published annually by NSW Agriculture and the Australian Cotton Cooperative Research Centre (ed. K. J. Schulze and A. R. Tomkins).

There are restrictions on the use of certain pesticides, and pesticide selection for a particular target may be influenced by the insect resistance management strategy which is developed annually by the Transgenic and Insect Management Strategy (TIMS) committee (see Figure 5.3).

Herbicides are usually classified into groups depending on when they are applied relative to the crop cycle and the crop’s sensitivity, both of which influence their application requirements. Refer to Section 6 for more information.



## 6. Pesticides

**Pesticide**      *A substance used to prevent, control, attract or repel pests or regulate plant growth.*

Using pesticides brings with it responsibilities towards

- People
- Environment
- Non-target areas, livestock and crops.

Pesticides are generally grouped to according to their purpose.

**Table 6.1. Common pesticide types.**

Pesticide type	Purpose
Herbicide	Kills weeds (or herbage)
Desiccant	Dries up plant leaves and stems
Defoliant	Removes plant leaves without killing the plant
Growth regulator	Changes normal plant or insect growth
Insecticide	Controls insects
Miticide	Controls mites
Larvicide	Controls insect larvae
Ovicide	Controls insect eggs
Fungicide	Controls fungi
Bactericide	Controls bacteria
Synergist	Improves the performance of pesticides

Pesticides range from common everyday products such as salt to complex chemical and biological agents. When handled incorrectly they can be dangerous to all living organisms including humans, birds, fish, bees, animals and plants.



## 6.1 Formulations

Pesticides are manufactured in different forms. A pesticide has three main components that together make up the formulation namely:

<b>Active ingredient</b>	Kills or controls the pest.
<b>Carrier or solvent system</b>	Stabilises the diluted product and aids coverage and application of the pesticides.
<b>Adjuvant</b>	Adjuvants are added to pesticide formulations to modify performance (usually to enhance it) or overcome some inhibiting factor.

All these components must be taken into account for the safe handling of the product.

Very few active ingredients are manufactured in Australia, but many companies formulate products here. Products are expected to remain stable and true to label specification for at least two years under reasonable storage conditions.

Cotton pesticides are available in many different formulations and the properties of these require different handling and application techniques.

### Hazards - Pesticide formulations

Handling	Certain formulations better suited to closed handling systems, storage and/or recyclable packaging.
Spillage	Liquid formulations more difficult to contain and clean up than solid formulations (eg. dry flowables).
Contamination	Liquid formulations more likely to be absorbed onto clothing, dusts more likely to be inhaled.
Flammability	Solid formulations reduce flammability.
Measurement	Volume easier than weight so reduces risk of incorrect dosage.
Evaporation	Solid formulations reduce risk of evaporation or volatilisation.
Drift	The formulation and application equipment selected must consider the risk of drift.

#### **Aqueous concentrates (AC)**      e.g. Gramoxone®

Water based concentrates that are stable, mix easily and need no agitation once a spray solution has been made up.

Paraquat and diquat react with negatively charged soil particles and wetting agents, and can lose activity in muddy water. Only non-ionic wetting agents should be mixed with them.

#### **Capsule suspension (CS)**      e.g. Promet® 365CS

Pesticides are formulated as very small 'microcapsules' that are 3 to 10µm diameter, with the active ingredient contained within a polymer 'capsule'. The encapsulation may slow the release of active ingredient, but cost per unit of active ingredient may be greater.



**Water dispersable granule (WDG) e.g. Diuron 900 WDG®**

When these granules are added to water each granule disperses - reducing the caking and uneven mixing associated with wettable powders. With low toxicity pesticides, the granules can be concentrated with up to 90% active ingredient which improves transport and storage efficiency.

Microgranules have flow characteristics similar to liquid and can be poured and measured volumetrically.

**Emulsifiable concentrates (EC) e.g. Thiodan EC®**

These are true liquids but are formulated as emulsions that turn a 'milky' colour when added to water. The active ingredient is dissolved in a solvent or petroleum oil, and then blended with a special surfactant or emulsifier.

When mixed with water, the product disperses to form an emulsion, with millions of minute droplets of oil each containing a small amount of the active ingredient. Well-formulated EC's mix easily and stay evenly dispersed without agitation after the initial stirring of the spray. However, it is advisable to apply EC's as soon after mixing as possible. If spray mixtures of ECs are left standing for several hours, it is possible for some separation of the oil and water fractions to occur. An oily scum forming on the surface of the milky coloured solution will indicate separation.

**Soluble liquid (SL) e.g. Folimat® 800 SL**

As with ECs, soluble liquids are true liquids but unlike EC's do not require an emulsifying agent in the formulation to mix with water. The active ingredient in SL formulations dissolves in water, and the resultant mixture does not turn a milky colour.

**Granules (G) e.g. Temik®**

Pesticides with high technical efficiency in pest control but with associated high levels of mammalian toxicity require a special formulation to lower the risk to applicators and the environment.

Examples include Temik® (aldicarb) and Thimet® (phorate). In both cases the product is a granule with a low percentage of active ingredient (10%-20%). Approximately 80% to 90% of the granule is composed of inert material. The active material is distributed through the inert mass to lessen the chances of contact in the event of accident.

Note: These products need special care in storage and handling and must be kept dry. The product label and MSDS directions and precautions **must** be followed.

**Dry flowables (DF) e.g. Diuron 900DF®**

Consist of very small granules of a consistent size, that disperse readily when mixed with water. Agitation is essential to maintain mixture consistency.

These products can be measured volumetrically and packaged in inexpensive containers (e.g. cardboard boxes with a plastic liner bag).

**Liquid concentrates (LC) e.g. PIX® Plant Growth Regulator**

Agitation is not required to maintain a spray liquid with the active component equally spread throughout its volume. Clean water is essential.



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**Suspension concentrates (SC)      e.g. Cotogard® 500SC**

These formulations are sometimes known as ‘flowables’. They represent a significant formulation advance on powders because potentially hazardous dust was eliminated and the liquid suspension could be poured and measured accurately by volume.

Flowables need vigorous shaking to ensure that the drum contents are properly mixed before measuring out. Drums of flowables that have been undisturbed in storage for even quite short periods (weeks) tend to slowly settle out and **must be shaken thoroughly** before use.

**Bio-formulations (Biologicals)      e.g. BTK Biological®, CoSTAR OF®**

Bio-insecticides are becoming more prevalent in the IPM programmes being adopted in cotton, as part of the BMP objective to reduce the dependence on inorganic pesticides. In addition, the newer generation bio-insecticides are far more effective with low risk to operators and the environment.

Bio-formulations often consist of a suspension of the biological agent in water, inert ingredients and/or nutrient medium, and are therefore similar to suspension concentrates.

**Wettable powders (WP)      e.g. Envirofeast®**

Wettable powders are becoming less common but at one time were the main solid formulation. The active constituent is milled to a fine (5 µm to 10 µm) consistency and then blended with dispersants, surfactants and some inert carrier. Most mix with water easily and quickly if agitated properly in the spray tank.

**Ultra low volume (ULV)      e.g. Decis Forte® ULV**

ULV's apply the active ingredient in a low evaporative carrier (oil) rather than water. In Australia, much cotton insecticide spraying is carried out during hot weather, so using ULV formulations minimises the risks associated with droplet evaporation. Using application equipment such as Micronairs, it is possible to achieve coverage of pests with volumes as low as 2 litres per hectare, which improves operator efficiency. These ULV formulations are exclusive to the Australian cotton industry where low volume aerial application is still used efficiently.

ULV formulations are loaded into application equipment (for application) directly from the original delivery packaging. They do not require intermediate handling or mixing and are therefore suited to closed handling systems that are safer for applicators. In general, ground rigs do not apply ULV formulations.

**Petroleum spray oils      e.g. white, mineral summer oil**

The most common spray oils are the petroleum spray oils (PSOs), which are derived from crude oil. They belong to the lubricating range of refined products, and are similar to baby oil and medicinal paraffins. Some of the spray oils are safe to use on cotton, particularly those blended with ultraviolet protection products to protect the product from ultraviolet (UV) light degradation.

Petroleum spray oils are used against a wide range of pests such as thrips, aphids, two-spotted mites, whiteflies, other sucking pests and *Heliothis*. The PSOs, particularly those with UV reduction properties, may improve the effectiveness of biological, synthetic



insecticides and bioherbicides. When PSOs are used as a stand alone product, they are slower to kill and have a lower kill percentage than synthetic insecticides. However, when used prophylactically as high volume-low concentration sprays, PSOs can suppress infestations of most cotton pests without disrupting beneficial insect activities. PSOs are therefore products that can be used in IPM systems.

### **PSOs as Emulsifiable concentrates**

When these spray oils are mixed with water, the product disperses as minute droplets of oil and forms an emulsion with the water. The emulsion appears as a “milky” colouring in water and this is a characteristic of the formulation. It mixes easily and stays in solution after the initial stirring of the spray, but will require agitation if left standing for a few hours to avoid a possible separation of the oil and water fractions. Once the oil is made up into a spray solution it is advisable to apply the solution soon after, or continue to agitate to avoid a possible separation of the oil and water fractions. Agitation should continue during spraying to ensure that the oil stays evenly dispersed. When the oils are used in combination with other products such as biological and synthetic insecticides, the mixture will require continuous agitation.

In mixing the oil with either biological or synthetic pesticides, the oil should first be mixed in water before the pesticide is added. High volume/low concentration sprays are recommended to allow multiple use of the oils and reduce the impact on beneficial insects. Good coverage is required for improved efficacy of PSOs.



## 6.2 Pesticide labels



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### Stop and read the label - it is a legal document

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All products must have a label that has been approved and registered by the National Registration Authority for Agricultural and Veterinary Chemicals (NRA).

This in turn means that if label directions are followed:

- (a) The **crop** will be protected efficiently from pest competition and attack.
- (b) **People** will not be put at risk.
- (c) **Environmental** impact will be minimal.

To allow flexibility and to enable quick action to counter shifts in pest pressure, a number of products are occasionally permitted to be used outside normal label constraints. In each case, special permission is given, provided the authorities in New South Wales and/or Queensland are convinced such approval is in the interests of all concerned.

Part of the clearance procedure for each pesticide involves a review by experts in the National Health and Medical Research Council (NHMRC). This review is to assess the likely risks to the health of users and consumers, so that suitable withholding period (WHP) and maximum residue limit (MRL) guidelines can be established for the product.

All agricultural pesticides contain important information on the type of pesticide, formulation, directions for use, safety and emergency procedures. In addition to the label, which must be affixed to the pesticide container, each product has a Material Safety Data Sheet (MSDS) which is available from the supplier.

The **first** step when considering pesticide use is to read each section of the label carefully (as outlined below). Each label layout is similar (according to NRA guidelines) and contains the following sections:

#### Poisons schedule (Signal headings)

A poison warning on a pesticide label indicates the potential health hazard of a pesticide to the user.

These red-on-white background signal headings always appear at the top of the label's central panel that bears the trade name. Additional warning statements may also be required by the NRA for particular pesticides.

Poison warnings advise users of the level of protection needed when using particular pesticides. This includes requirements for special protective equipment, which are set out in detail on the label under '**Safety Directions**'.

The higher the schedule number, the greater the level of care (including amount of protective clothing and equipment) needed during handling, storage and use of pesticides.



Most herbicides and fungicides are either exempt or are in Schedule 5. A few are in Schedule 6. The herbicide paraquat is in Schedule 7 but this is exceptional for a herbicide. Most insecticides are in Schedules 6 or 7, except for low-strength domestic fly sprays, which are exempt. Schedule 7 pesticides also have much stricter controls placed on their supply and availability than S5 and S6 pesticides.

All pesticides are classified into one of four Poison Schedule categories. The four categories and accompanying special warnings are:

**Table 6.2. Poisons schedules and label warnings - pesticides.**

	Schedule	Description	Toxicity	Label
	<b>Exempt</b>	Substances not recommended for scheduling	Very low	<b>KEEP OUT OF THE REACH OF CHILDREN</b>
	<b>5</b>	Poisons of a hazardous nature that must be readily available to the public, but require caution in handling, storage and use.	Low to moderate. Handle with caution	<b>CAUTION</b> <b>KEEP OUT OF THE REACH OF CHILDREN</b> <b>READ SAFETY DIRECTIONS BEFORE OPENING OR USING.</b>
	<b>6</b>	Poisons that must be readily available to the public, but are of a more hazardous or poisonous nature than those classified in Schedule 5.	Moderate to high Poisonous	<b>POISON</b> <b>KEEP OUT OF THE REACH OF CHILDREN</b> <b>READ SAFETY DIRECTIONS BEFORE OPENING OR USING.</b>
	<b>7</b>	Poisons that require special precautions in manufacture, handling, storage or use.	High to very high Exceptionally poisonous	<b>DANGEROUS POISON</b> <b>KEEP OUT OF THE REACH OF CHILDREN</b> <b>READ SAFETY DIRECTIONS BEFORE OPENING OR USING.</b>

Always read the product label for specific safety instructions. As a guide the following PPE should be worn as minimum protection:

### Exempt



Wear rubber gloves and face shield when handling the pesticide.

### S5



Wear rubber gloves and face shield when handling the pesticide.

### S6



Wear waterproof clothing, rubber gloves and face shield when handling the concentrates.

### S7



Wear protective rubber gloves, eye protection, waterproof clothing, and an agricultural respirator during all operations including spraying.

Pesticide products may appear in more than one poison schedule if the products contain different active ingredients or solvents. Cotton pesticides that need special attention to safety include the carbamates, organophosphates and some of the more active synthetic pyrethroids.

## Pesticide label information.

**Example only**

### Poison schedule and any relevant Dangerous Goods information

See Sections 5.2 and 5.3.

### Trade Name (Distinguishing Name)

The Trade Name is the proprietary name under which the product is marketed. The name may be protected under Patent and Trademark legislation.

The Distinguishing Name must include words and/or phrases that distinguish the product from all others and identify its use,

*Example:* Thiodan® EC Insecticide

### Active Constituents

The active constituent is the biologically active component of the product. Active constituents are listed on the label under the Trade Name and are usually expressed as grams per kilogram (g/kg) or grams per litre (g/L).

When the active ingredient is a scheduled poison, the chemical name must be in capital letters. If the active ingredient is a cholinesterase inhibitor the words 'an anticholinesterase compound' must appear after the active ingredient. It is also a requirement to declare certain solvents at prescribed levels, underneath the active constituent statement.

*Example:*

Active constituent: **350 g/L ENDOSULFAN**

Solvent: **640 g/L LIQUID HYDROCARBON**

### Statement of Claims for Use

This section is a short statement of the purposes for which the product is registered

*Example:*

For the control of *Heliothis (Helicoverpa spp.)* and various other insect pests on Cotton, Oilseeds, Vegetables and Other Crops.

### Prohibition and Restriction Statements

Where specific restrictions or prohibitions are imposed by State Government authorities, details will be presented in bold letters on the main panel of the label.

*Example:*

**Restricted chemical product - only to be supplied to or used by an authorised person.**



## Net Contents

## Example only

The net contents of the container expressed in metric units, e.g. 20 L, 5 Kg NET.

## Directions for use

Due to space restrictions on the container label, many pesticides now have a booklet containing the directions for use (and other important information) attached to the main label. There is one booklet attached to each container. Read this booklet!

It is good practice to provide these booklets to personnel involved with the application of pesticides so that they have a 'ready reference' which can be carried in a vehicle or in their pocket during application.

The directions for use are usually set out in a table that lists:

- Crops where the product can be used,
- Pest (insect, disease or weed) that is being targeted,
- States where the particular usage is registered,
- Rate of product to be applied (e.g. L/Ha, L/100L water),
- Withholding Period (WHP),
- Critical comments - Advice that relates to that specific use of the product or is important in the general performance of the product.

Included in the 'Directions for Use' are restraints statements which advise what NOT to do with the product during mixing and application.

## Use limitation statements

The limitation statements appear immediately below the 'Directions for Use'. These are general restrictions on the use of the product. *For example:*

**NOT TO BE USED FOR ANY OTHER PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION.**

Residue management statements are included in this section, including the detailed withholding period if these have not been shown in the 'Directions for Use'.

## General instructions

This section of the label contains important information which is not contained in the 'Directions for Use' or elsewhere on the label. Subjects which are often included in this section are:

- Mode of action (including anti-resistance strategies).
- Equipment usage, maintenance and cleaning.
- Mixing instructions.
- Compatibility statements.



## Example only

The following general instructions may also be included:

<b>Insecticide Resistance Warning</b>	<i>A warning on the possibility of insects developing tolerance and/or resistance to the product.</i>
<b>Export of Treated Produce</b>	<i>Advice on minimum residue levels for foodstuffs which may have been treated with the product.</i>
<b>Compatibility</b>	<i>Compatibility of the product with other pesticides in tank mixes.</i>
<b>Application</b>	<i>Advice on application methods and the best conditions. Specific mandatory restrictions are included.</i>
<b>Precautions</b>	<i>Precautions to be taken when using the product and for the protection of non-target species and areas. Specific advice on storage, handling and disposal of containers. This information should be considered in the BMP / PAMP process.</i>

### Special restrictions

Where particular restrictions have been placed on the use of the products, an additional section provides details of the restrictions.

*Example:* **CONDITIONS OF USE ON COTTON**

### Precautions

The precautionary statements relate to:

- Protection of crops, native and other non-target plants, livestock, wildlife, fish and other aquatic organisms and the environment,
- Special hazard warnings for fish, other aquatic species, bees, livestock and the environment,
- Precautions when entering treated areas or handling treated crops,
- Storage, handling and disposal procedures,
- Fire safety precautions.

### Safety Directions and First Aid

The National Health and Medical Research Council (NHMRC) specify these directions as part of the product registration process.

All personnel involved with the transport, storage, mixing, application and/or disposal should familiarize themselves with this section before opening the container or package.

### NRA Approval No.

The NRA Approval number indicates that the product has attained clearance for the purpose shown on the label.



## 6.3 Material Safety Data Sheets (MSDS)

MSDS stands for **Material Safety Data Sheet**. It contains more detail (than the label) regarding the physical nature of the product, the dangers associated with accidental exposure to it and how to proceed in the event of an accident.

There is an MSDS available for **every** pesticide and these will be supplied **on request** where chemical supplies are obtained.

Cotton growers and applicators should ensure that all personnel who are handling and applying pesticides read the label and have access to the relevant MSDS information at all times.

A MSDS consists of five main sections:

### Statement of Hazardous Nature and Company Details.

#### Identification

Details which identify the pesticide and ingredient properties.

#### Health Hazard Information

Health effects from exposure to the pesticide and first aid guidelines.

Advice to Doctor: In the event of poisoning, ensure that these details accompany the patient to hospital.

#### Precautions for Use

Guidelines relating to equipment and procedures for mixing, application and disposal. Details of personal protective equipment to be worn while in contact with the product are shown. All employees who are involved in the application process should be aware of these precautions.

#### Safe Handling Information

Guidelines relating to equipment and procedures to be used during handling, transport and storage of the product. All employees who are involved in handling the product should be aware of these precautions.







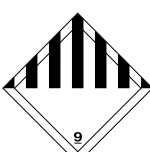
Emergency Contact Numbers for the product are shown at the front and at the end of each MSDS.



## 6.4 Symbols on chemical containers

Dangerous goods symbols and signs are placed on containers and in MSDS sheets to provide a clear indication of particular hazards. These are referred to as Dangerous Goods Class Diamonds. Personnel should be aware of what each of these means so that pesticides can be handled properly.

Examples of Class Diamonds that refer to pesticides include:

<u>Description</u>	<u>Class</u>	<u>Sign</u>	<u>Example*</u>
Poison gas	2		Methyl Bromide
Flammable liquids	3		Lannate <sup>®</sup>
Dangerous-when-wet solids	4.3		Fumitoxin <sup>®</sup> tablets
Oxidising agents	5		Ammonium Nitrate fertilizer.
Poison	6		Spray Seed <sup>®</sup>
Corrosive substances	8		Ethephon <sup>®</sup>
Miscellaneous dangerous goods	9		Karate <sup>®</sup>

*\* Note: These are examples only and each pesticide container and MSDS should be checked.*



As well as Class Diamonds which indicate the hazardous nature of the pesticide, Packing Group numbers indicate the level of any danger.

In addition to the dangerous goods symbols, other signs may be posted on the containers, packaging and transport. Examples are shown below, but if there is any doubt, you should consult your chemical supplier or the manufacturer, so that the hazard rating of the product can be established prior to use.

Other signs



Chemicals may have more than one dangerous goods label. For example, if a product is a poison and is also flammable, it would have both Class 6 and Class 3 labels.

Manufacturers and suppliers can provide pesticide applicators and growers with more information on safety symbols and signs.

## 6.5 Transport

Safe transport of pesticides is often overlooked when moving pesticides from stores to the farm, but proper planning and management of this aspect of pesticide usage are essential. It is advisable to request the chemical reseller to deliver pesticides to the farm or loading area, because they have properly equipped vehicles and trained personnel.

### Hazards - Pesticide transport

Vehicle(s)	Unsuitable or unroadworthy vehicles increase the risk of spillages and/or accidents.
Personnel	Untrained personnel increase the risk of accidents and may not respond properly in the event of spillage or contamination.
Handling	Pesticide containers must be handled, loaded and unloaded carefully to avoid damage or leakage occurring.
Personal safety	Pesticides must not be carried in the cabin with personnel; protective equipment (including safety equipment) should be worn whilst handling pesticide containers.
Security	Pesticides must not be left in areas where unauthorized personnel may have access to the containers, or weather may damage the packaging.

Following a few guidelines will reduce the risk of accidental exposure or spills:-

- The vehicle design must be suitable for farm chemicals. The cab must be separate from the load area. Never carry pesticides in the passenger compartment of a vehicle.
- Vehicles must be free of defects that may affect the safety of the load or occupants.
- The load area should be clear, dry and free of protrusions that may damage packages.



- The load area should be fully enclosed. Pesticides should be protected from high temperatures and moisture during transit.
- Vehicles containing pesticides should not be parked in residential areas, apart from pick-up or delivery.
- Transport routes should be selected to avoid residential and sensitive areas.
- Check that all containers and packages are complete (i.e. no leakage or potential leak points) before loading.
- Consult your supplier or the Australian Dangerous Goods Code before transporting mixed loads.
- Drivers should be properly trained.

### **Loading and unloading**

- Observe safe work practices when lifting or moving pesticide containers.
- Wear appropriate safety and protective equipment.
- Do not exceed equipment safe working load (SWL) limits.
- Check all packs prior to loading. Damaged packs should be replaced.
- Distribute the weight evenly on the vehicle.
- Don't stack drums and liquids on top of cartons.
- Secure the load.
- When unloading, do not drop pesticide containers!
- Have spillage safety equipment accessible during unloading operations.
- If the pesticides are not being used immediately, unload them into a proper storage area.

## **6.6 Safe storage**

This section focuses on the storage of chemicals on-farm. For guidelines on the handling and storage of large quantities of pesticides, refer to Australian Standard AS 2507-1998.

Use of pesticides in cotton necessitates storage of limited quantities on or near the farm so that they are available for immediate use. All personnel have a duty of care to lower the risk of exposure and accident to other personnel and the environment.

Pesticides may be stored in:

- a room in a designated storage building, provided that the room is separated from other parts of the building by floor-to-ceiling walls.
- a separate chemical store room.
- a secure open storage area.
- a locked cupboard (small quantities).

Pesticides should always be stored in their original labelled and registered containers. They should never be stored in soft drink bottles or other food or drink containers, nor alongside seed or livestock foodstuffs.



The best choice of storage of pesticides is a secure, well-ventilated building that is used solely for pesticides (i.e. no animal feed is stored with the pesticides). Keep chemical groups apart (e.g. herbicides and insecticides) to prevent contamination and check product labels and MSDS for specific storage requirements.

### **Hazards - Pesticide storage and mixing areas**

Education	Insufficient training may lead to accidents (e.g. chemical & handling safety).
Pesticide type	Selection of incorrect pesticides may lead to personal injury, crop contamination and other adverse consequences.
Construction	Incorrect construction and location may increase the risk of accidents or other adverse outcomes.
Spillage	Stores should be constructed to contain and control spillages.
Contamination	Measures must be taken to prevent personal contamination (e.g. lockable stores, provision of PPE, warning signs).
Flammability	Many pesticide solvents are flammable.
Combinations	Products that are not segregated may combine and increase risks.

The following points, which apply to an on-farm store, will assist growers. If a large or commercial storage is planned then relevant building codes should be used.

### **Site**

The site should:

- be well above the highest recorded flood level, (or adequately protected from flooding) and pose no threat to waterways,
- be at least 10 metres from other buildings and at least 15 metres from the property boundary,
- have adequate airflow and be clear of obstructions or fire hazards,
- be positioned to allow adequate access for machinery and vehicles and easy loading/unloading,
- have access to a clean reliable water supply.

*Note: Distances are absolute minimums and owners should assess their properties and site the storage in the safest practical location on their property.*

### **Building**

- Make the store large enough for the farm requirements, whilst leaving enough space to move containers around.
- Make the store large enough to separate pesticides according to their Dangerous Goods class and ensure that herbicides are well separated from other pesticides. Signage to indicate the herbicide area would assist workers and minimize the risk of contamination.
- Floors should be concrete, nonslip and self-draining to an evaporation pit or sump that can be pumped. Keep the floors clear and free of obstructions, by using shelves and pallets to store chemicals.



- The store should be banded to contain 25% of the total liquid in the store at any time plus 100% of the largest container stored at any one time.
- Fire and chemical resistant building materials should be used.
- There should be adequate ventilation and the use of roof or wall vents is recommended. Ventilation openings should be meshed to prevent wildlife and/or children from entering.
- There should be access to fresh water, and emergency shower and eye wash facilities should be installed.
- Ensure adequate lighting. Natural light is preferred (lower fire risk).
- Doors and windows must be strong and lockable.
- A separate lockable cabinet is recommended for highly toxic products.

## Safety

- Personal protective equipment (PPE), and an adequate supply of clean water must be accessible in case of personal contamination.
- A dry-powder fire extinguisher should be mounted just outside the store entrance, and a spillage kit located nearby.
- A well-ventilated site outside the enclosed storage is advisable for mixing pesticides and storing used containers.
- If unused (mixed) pesticide is returned to the store, it should be stored in a dedicated 'short-term' holding tank that has been labelled properly.
- Appropriate dangerous goods signs should be posted at the building entrance, with a large sign (see example below) posted at the main site entrance.



## 6.7 Mixing

**Read the label and MSDS information.**

**Do not smoke or drink during the mixing process or before personal decontamination has been completed.**



### Hazards - Mixing pesticides

Handling	Pesticide containers can be heavy. Use correct lifting techniques, procedures and equipment to prevent injury or spillage.
Spillage	Risk to personnel and the environment.
Overflow	Overfilling of spray or mixing vats.
Poisoning	Inhalation, absorption or ingestion of pesticides or mixtures.
Contamination	Personal or environmental from spills or longer term exposure.
Waste	Incorrect disposal of containers and/or excess pesticide resulting in contamination of environment or personnel.
Combustion	Volatile solvents or pesticides may be ignited.
Combinations	Some chemical combinations are incompatible and mixing them may lead to unpredictable results, personal injury and/or crop damage.

### 6.7.1 Before mixing

- Considerations to reduce risks during mixing include using:
  - less volatile formulations,
  - less toxic pesticides,
  - easy-to-handle formulations (e.g. dry flowables) and packages,
  - personnel rotation schedules (i.e. rosters) to limit exposure.
- Where possible, eliminate or reduce the operator's contact with the concentrate. Using closed loading systems, auto fillers and concentrate suction spears or hoses can do this. If personnel are handling concentrate, gloves and eye protection should always be worn, and additional PPE should be worn if advised on the label.
- Always mix in a well ventilated, secure area.
- Stay upwind when mixing concentrates. Do not eat, drink or smoke during mixing or refilling. Cover (dress) all small wounds and protect using PPE.
- A plentiful supply of fresh water and washing facilities should be available near the mixing area so that mixers can wash frequently, and operators can wash before entering the cab.



- Calculate required volumes and prepare equipment before opening the concentrate containers.
- Measuring equipment for both liquids and solids (e.g. powders or granules) should be available in the mixing area. Measuring jugs should have accurate measurement markings, be robust and chemical resistant. A premixing bucket may be required for wettable powder formulations. Automated measuring and dispensing systems should be used where large volumes of concentrates are being mixed. These systems should be 'closed' so that operators are never in contact with the pesticide.
- Do not use measuring equipment or chemical handling equipment for other purposes. If chemical combinations are being prepared, clean the measuring equipment between dispensing concentrates to prevent incompatibility problems or reduced efficacy of the pesticides.
- Always half fill the tank or mixing vat with water (if required) before adding concentrates. Add the concentrate components slowly, with pauses for agitation. Pesticides such as ULV's should be added slowly (and preferably via a closed system) to the spray tank to avoid splash back. Do not leave the mixing area until the operation has been completed and equipment has been stored properly.
- Take care when opening drums as temperature changes may have caused a pressure build up. Always open drums while they are upright.
- Bags should always be opened by cutting the outer and liner with a sharp knife - do not tear the bag open.
- Cartons should be opened from the top as there is usually a plastic liner with a fastener under the top flaps.
- Avoid pouring concentrates from above waist height. Use a loading platform alongside, or attached to, the spray tank or vat.
- After emptying a container, store it upright with the lid on until proper rinsing and/or disposal procedures can be followed.
- All handling and dispensing equipment should be thoroughly washed and decontaminated after use.

**Never allow unauthorised personnel into the mixing area.**

**Never stir chemicals with your hand or arm.**

### 6.7.2 Agitation

The premixing vat or spray tank must have good agitation. Use the tank agitators to mix the chemical before (or while) proceeding to the application area.

Whenever a solid active constituent is used (e.g. wettable powders, dispersable granules or suspension concentrates), good spray vat agitation will be needed to keep the spray output consistent. Failure to do this will result in varying degrees of settling towards the bottom of the vat during the spraying operation. Poorly mixed pesticides will be less effective and may damage or block equipment.



### 6.7.3 Water quality

The quality of water available for making up spray solutions on farm is very variable. In some cases it is of such poor quality that it can seriously affect pesticide activity in the spray vat prior to spraying. Check the bottom of the spray tank and the filters for any signs of sedimentation or other incompatibilities with the water being used.

As part of best farming practice, a water test should be done annually on each water source to check the quality and suitability for use in spray mixtures. There are a number of factors that must be borne in mind when assessing water suitability and these are:

#### Water acidity/alkalinity (pH)

Two of the major insecticide chemical groups, the organophosphates and the carbamates, degrade by hydrolysis (interaction with water) when they come into contact with water that is alkaline. On the pH scale used to measure acidity/alkalinity the neutral point is pH 7.0. Many bores produce alkaline water of pH 8.0 to 8.5. A number of acidifying buffering agents (e.g. Primabuff®) have appeared on the market to counter this destabilising effect, but an accurate idea of the pH needs to be obtained to work out dose rates. Check that the buffering agents are compatible with the pesticides and formulations being used.

#### Water clarity

The suspended solids, especially clay and silt fragments, that make some water supplies brown in colour not only clog filters and wear nozzles by constant abrasion, but can interact with some pesticides. For example, non-residual herbicides such as glyphosate, paraquat and diquat, binding to the clay is such that the active chemical is no longer free to work on its target weed. It is advisable to use only clear, settled water for sprays and if none is readily available, consider the possibility of using alum (aluminium sulphate) to flocculate and sink the suspended solids present.

#### Calcium and magnesium salts

Alkalinity in spray water is often associated with a high level of so-called 'hardness' caused by calcium and magnesium salts. Many pesticide formulations include components to overcome the reaction of calcium and magnesium with the formulation. In extreme cases water could be treated to give additional protection. The problem is minimised if spray solutions are applied shortly after mixing.

### 6.7.4 Adjuvants

An adjuvant is any substance added to a spray mixture to modify its performance (usually to enhance it) or overcome some inhibiting factor. Applicators should seek advice from the manufacturer and supplier of the pesticide regarding how the addition of an adjuvant will affect pesticide performance. Always read the label to ensure that the adjuvant is compatible with the pesticide, formulation and application method being used.

#### Wetting agents

e.g. BS1000®

Labels will always indicate whether a wetting agent or surfactant is required. This may be dependent upon the volume applied. Non-ionic wetters are normally used, but check label recommendations carefully.



.....

Wetting agents increase pesticide coverage by reducing surface tension on the leaf surface so that the droplet spreads over a larger area.

**Stickers** **e.g. Bond<sup>®</sup>**

Labels will always indicate whether a sticker is required. Stickers increase adhesion of the spray mixture on the target and reduce droplet bounce.

**Thickeners** **e.g. Xanthanum gum**

Thickening agents increase the viscosity of the mixture.

**Buffering agents** **e.g. Primabuff<sup>®</sup>**

Some chemical groups including the organophosphates and carbamate insecticides become destabilised in alkaline spray water. Proprietary buffering (acidifying) compounds are available to counter this effect if the available water has a pH greater than 7.

**Other additives**

Monsanto recommends the addition of 2 kg of Sulphate of Ammonia per 100 L spray volume to Roundup<sup>®</sup> sprays. This promotes consistent performance and assists in overcoming antagonism in certain mixed sprays. Formulations containing Sulphate of Ammonia (e.g. Liquid Ammo<sup>®</sup>) are also available.

Check product labels for specific requirements.

### **6.7.5 After completion of mixing**

- Store all concentrates and unused mix properly.
- Clean all measuring and mixing equipment thoroughly.
- Decontaminate (if required) after cleaning.
- Wash and/or clean all PPE ready for the next application.
- Update records for the chemical(s), stocks and application.

## **6.8 Chemical combinations (mixtures)**

### **Before combining pesticides - Read the label.**

#### **Many pesticides have a compatibility statement included on the label.**

It is common practice to combine two or more pesticides in a spray mixture to save time, labour and machinery costs. However, because of the great variety of pesticides now available, the effects of water quality and increased legal liability, most pesticide manufacturers are guarded in their claims of compatibility between different pesticides. Specific information is available from chemical companies and suppliers on request.

Combining different pesticides can result in problems of application or efficacy of pest control due to incompatibility of the chemicals in the pesticide formulations.



Wherever possible, mixtures should be avoided unless recommended by the manufacturers or unless the chemicals have been shown to be compatible through extended use.

- Combinations (mixtures) should be avoided if at all possible.
- If mixtures are contemplated, the manufacturer's instructions and label advice should be followed carefully. Use mixtures which have been proven by extended previous use in a range of situations.
- Where information is unavailable, and mixtures unavoidable, use the following test as a rough guide for assessment of possible mixture problems.

### Test for compatibility.

- (1) Use a clean clear glass jar such as a 1 litre container.
- (2) Make up 500 mL of correctly diluted spray mixture. Use the same water that is normally used as a carrier for sprays at the same temperature, i.e. ambient temperature.
- (3) Add the products in the same sequence as given below. Agitate after each addition.
- (4) Shake the jar vigorously and let stand for 15 minutes. If scum, clumps or any precipitate forms, the mixture is not compatible. Similarly, a mix that generates heat should not be used.

**NOTE: This test is a guide only. Always refer to the pesticide label, manufacturer and supplier for the most up to date information.**

If an untried mixture is going to precipitate, it is better for it to occur in a bottle than in the spray tank. However, the absence of any obvious physical change is not a foolproof indication of absolute compatibility.

The order of adding different formulations to the tank should be:

- |               |   |
|---------------|---|
| <b>First</b>  | Wettable powder or water dispersable granule or soluble powder, |
| <b>Second</b> | Suspension concentrate (flowable) or miscible liquids,          |
| <b>Third</b>  | Adjuvants or wetters / spreaders / stickers,                    |
| <b>Fourth</b> | Emulsifiable concentrates or crop oils.                         |

Measuring equipment should be cleaned after the addition of each product to avoid interactions between concentrates. Failure to clean the equipment may result in physical incompatibilities or reduced biological activity.



## 6.9 Protective equipment

### 6.9.1 Personal protective equipment (PPE)

Whilst every pesticide label should carry instructions on the minimum protective clothing to be worn, the following equipment and clothing should be used when handling all agricultural pesticides. General guidelines for PPE and hazard to the environment for common cotton pesticides are available from Cotton Australia.

#### Clothing



Cover as much of the body as possible, especially the face, neck, chest and forearms. Personnel involved in mixing large quantities of pesticide should wear washable fabric overalls and waterproof boots. **Wear trouser legs outside the boots.**

A spare, clean set of PPE clothing should be available in case of an accident or contamination.

#### Gloves and boots



Never use leather or cloth materials because they absorb pesticide and provide a constant source of contamination. Gloves should be unlined for the same reason and worn inside the sleeves. Gloves must be made of water proof and chemical resistant materials.

#### Face and eyes



Washable hats, protective glasses or goggles, spray helmets and face shields are important for handling concentrates.

#### Respirators



Choose the correct type of respirator with the correct cartridge. Replace cartridges regularly and write the installation date on each cartridge. Ensure that the respirator fits well (especially around the nose) and store safely in a cool, dry, dark place when not being used.

Respirator design and cartridge type should conform to Australian Standards 1715-1994 and 1716-1994 and be the correct type to protect the user from the pesticide being handled.

### 6.9.2 Controlled atmosphere equipment (CAE)

#### Air-conditioned cabs

An air-conditioned cab can reduce a spray operator's exposure to the pesticide being sprayed. The normal paper elements fitted to an air conditioner's intake will not prevent pesticides from entering the cab and these must be replaced with activated charcoal filters.

Care must be taken not to contaminate the cab, especially with concentrate. The best means of



avoiding this is to have separate personnel for mixing and loading. Alternatively, the operator should have separate protective clothing and equipment for filling and mixing and wash properly before re-entering the cab so that the cab interior is not contaminated.

Ensure that the cab is sealed during filling operations in case of spillage or odours.

### **Forced air hoods and helmets**

Personal hoods and helmets that have forced air ventilation have limited applicability for field application of pesticides in cotton. They may be used where a small open vehicle or 4WD motorcycle is being used for spot spraying. PPE which allows greater mobility is the preferred option.

## **6.10 Protecting others**

### **6.10.1 People management and safety**

The overall enterprise manager has a responsibility to put in place a work environment in which properly trained employees, including himself, can use pesticides safely and effectively.

This entails provision of:

- Safe spray mixing facilities,
- Safe and secure storage of chemical stocks,
- Safe transport of pesticides when required,
- Adequate safety and first aid facilities.

Adequate training is essential for all personnel who are involved in pesticide application. Items under this heading would include:

- Safe operational routines,
- Knowledge of both label and MSDS contents,
- Good personal hygiene routines,
- Awareness of chemical handling responsibilities,
- Knowledge of local emergency procedures.

### **6.10.2 Monitoring exposure**

Anyone who is exposed to pesticides on a regular and continuous basis may wish to have blood or urine tests to determine the adequacy of their protection equipment and safety habits. The test usually determines any chronic effect of pesticides from organophosphates or carbamates. Blood tests are of little value for non-accumulating pesticides such as organochlorines or pyrethroids as the timing of the tests are critical and the pesticides are quickly expelled from the body.

Where individuals wish to be tested, monitoring must begin at least one month prior to exposure so a baseline or reference point for that individual can be determined. Every individual will have a different baseline. Testing should then be done early in the season (after 1–2 sprays) and then later in the season. Testing will need to be organised in conjunction with your doctor and samples analysed by any of the private pathology laboratories. All samples from the one individual need to be analysed by the same laboratory.



## 6.11 Poisoning

Poisoning accidents are usually the result of contamination with the pesticide concentrate. Contamination is most likely to occur during initial measuring out and preparation of the spray solution. Accidental splashing, when loading, is probably the major source of exposure.

Due consideration should be given to continual exposure to spray drift and to entering sprayed paddocks that are still loaded with active residues. Cotton chippers and insect scouts require advance advice if the fields have had recent pesticide applications, and minimum re-entry periods should be observed.

**Table 6.3. How pesticides enter the body.**

<b>Pesticides enter the body in three ways:</b>		<b>First Aid</b>
Orally	<ul style="list-style-type: none"> <li>- direct by drinking</li> <li>- splashes</li> <li>- while eating or smoking</li> <li>- eating sprayed products</li> <li>- by cleaning nozzles by mouth</li> </ul>	<p>Wash the contaminated area with clean water.</p> <p>Check the MSDS and label, and follow the directions if possible.</p> <p>Do not administer anything by mouth to an unconscious person.</p>
Inhalation	<ul style="list-style-type: none"> <li>- breathing, in spray droplets</li> <li>- working in enclosed buildings,</li> <li>- not using PPE.</li> </ul>	<p>Move the patient to a well-ventilated area with plenty of fresh air.</p> <p>Loosen the victims clothing. Apply artificial respiration if the patient has stopped breathing.</p> <p>Keep the patient warm and calm. Apply extra clothing or a blanket if necessary.</p>
Dermal	<ul style="list-style-type: none"> <li>- absorption through the skin <b>Absorption through the skin is the most common hazard to pesticide users. The risk increases when perspiring or when the skin is broken.</b></li> <li>- absorption through the eyes.</li> <li>- chemical burns.</li> </ul>	<p>Drench the affected area with water.</p> <p>Remove all contaminated clothing.</p> <p>Wash the affected area thoroughly with soap and water, but <b>do not</b> scrub the skin.</p> <p>Clean under fingernails and toenails if necessary to remove all traces of the contaminant.</p> <p>Follow the above procedures.</p> <p>Hold the eyelid open and flush with a gentle stream of clean water for at least 15 minutes.</p> <p>Do not use any soap or cleaners to wash the eye.</p> <p>Immerse the affected area in clean, cold water for 10 to 15 minutes.</p> <p>Bandage lightly with a sterile dressing.</p>



**Wash thoroughly before eating and drinking and change into clean clothes at the end of the job.**

- Treat all contamination as a serious incident, and implement procedures accordingly.
- Persons attending a contamination incident should ensure personal protection to prevent additional poisoning occurring.
- Check the MSDS and label, and follow directions if possible.
- Call the Poisons Information Centre, a local doctor and the ambulance.
- Put the patient out of the sunlight, in a well-ventilated location which is away from the contamination or other pesticides.
- Stay with the patient and direct other personnel to obtain medical attention and guide them to the patient.
- Advise other personnel so that they can observe the person who has been contaminated for signs of poisoning.

## **First aid kit**

A basic first aid kit should be kept at the storage and mixing facility and in any field vehicle that is used for pesticide application. Items that should be included in a first aid kit for pesticide poisoning are:

Clean water,  
 Soap, towel and small brush (e.g. nail brush),  
 Clean clothing and a clean blanket,  
 Atropine tablets (bottle of 20),  
 Ipecac syrup to induce vomiting,  
 Boric acid or other mild antiseptic; Methylated spirits,  
 Shaped plastic airway for artificial respiration,  
 Specific items as specified in MSDS for pesticides being used,  
 Instructions for use for the items in the first aid kit (see below).

**Poisons Information Centre (PIC)**

**Australia Wide 131 126**

**24 hours**



.....

## First aid in the event of poisoning

If any person is exposed to a significant quantity of pesticide (e.g. in the event of an accident), always presume that poisoning has occurred and implement emergency first aid procedures.

If a person starts to feel ill or develop symptoms while working with pesticides or within 24 hours after exposure, they should stop work immediately and seek medical attention.

Symptoms may include one or more of the following:

- blurred vision
- headaches
- dizziness
- nausea or vomiting
- chest pain
- breathing difficulties
- skin rashes
- drowsiness
- unconsciousness.

Ring the Poisons Information Centre (131 126) and seek professional medical assistance. It is important to have the pesticide label and MSDS available for consultation during discussions with both the PIC and medical professionals. First aid should be given as soon as possible after exposure to pesticides and whilst waiting for medical personnel to arrive.

### *Poison on the skin*

1. Drench the affected area with water.
2. Remove all contaminated clothing.
3. Wash the affected area thoroughly with soap and water (**Do not scrub the skin**).
4. Clean under fingernails and toenails if necessary.
5. Wash the skin with methylated spirits.
6. Seek medical attention.

### *Poison in the eye*

1. Hold eyelid open and wash with a gentle stream of clean water for at least 15 minutes.
2. Do not use soap, cleaners or other chemicals to wash the eye.
3. Seek medical attention.

### *Inhaled poison*

1. Move the patient to fresh air.
2. Assisting personnel should avoid being exposed to the pesticide.
3. Loosen the victim's clothing.



4. Apply artificial respiration if the victim has stopped breathing.
5. Keep victim warm and calm: wrap them in a blanket or extra clothes if necessary.
6. Seek medical attention.

#### *Swallowed poison*

1. Call a doctor, ambulance or the Poisons Information Centre (131126) immediately.
2. If the label or MSDS recommends giving an antidote by mouth, then do so; do not attempt to give anything by mouth to an unconscious person.
3. Seek medical advice as soon as possible.

#### *Burns*

1. Immerse the affected area in cold water for 10 to 15 minutes.
2. Bandage lightly with sterile dressing.
3. Seek medical attention.

## 6.12 Pesticides in the environment

Pesticide labels and MSDS have information about protection of the environment and how to dispose of the product safely. This information is detailed under the “Protecting wildlife, fish, crustacea and the environment” section of the label (see Section 6.2).

Many pesticides are toxic to aquatic organisms, bees and birds and all practical measures to avoid non-target effects on these species should be taken. The following guidelines for the protection of aquatic organisms, bees and birds are adapted from “Cotton Pest Management Guide -2002/2003” (2002) by K. J. Schulze and A. R. Tomkins.

### **Protecting aquatic organisms**

- Prevent pesticide drift onto surface waters or seepage into ground water,
- Locate storage, mixing and loading facilities away from surface water bodies,
- Plan pesticide storage, mixing and loading facilities with bunding and sumps to prevent contamination of water bodies,
- Install equipment that prevents back-flow when filling spray tanks from surface waters or other water stores,
- Avoid applying pesticides onto fields that are under irrigation or have free-standing water in the field,
- Build sufficient on-farm storage capacity (refer to Best Practices Manual) to contain pesticide contaminated tail water from cotton fields,
- Spraying in an upstream direction, when it is necessary to spray near watercourses, to reduce the maximum concentration at any one point,
- Use only registered products to control aquatic weeds,
- Do not dispose of empty pesticide containers or unused pesticides in surface water, on flood plains or in catchments when they could contaminate water courses.



## Protecting bees

Many pesticides are toxic to bees and can damage productivity if the bees or hives are contaminated. Some pesticides have specific warnings on the label such as:

### **Dangerous to bees**

**DO NOT spray any plants in flower while bees are foraging.**

Pesticide risk to bees can be reduced by:

- Applying pesticides in the early morning or in the evening when bees are not foraging,
- Notify the apiarist when spraying is scheduled so that he can remove the hives,
- If possible, use EC or granular formulations in preference to wettable powders which are particularly hazardous to bees,
- Use equipment that minimises drift, especially when crops and plants that are adjacent to the spray area are flowering,
- Avoid contamination of water where bees may drink.

## Protecting birds

Organophosphate and carbamate insecticides can be particularly toxic to birds, especially in granular formulations. Risks to birds from granular products can be managed by:

- Ensuring complete incorporation of the product beneath the soil (particularly at row ends where spillage may occur),
- Cleaning up spillages immediately.

Bait formulations for the control of rodents or soil insects may also be hazardous. The risk to birds from baits can be managed by:

- Ensuring even bait distribution, with no local concentrations of material,
- Not baiting over bare ground or in open situations where birds may see the baits,
- Not baiting near bird habitats such as remnant vegetation,
- Use of bait stations that do not allow access by birds,
- Only baiting where pest pressure is high (as confirmed by field checks),
- Baiting late in the afternoon when birds have finished feeding,
- Prompt collection and burial of rodent carcasses where these occur in open situations,
- Immediate clean-up of all spillages.

Insecticide sprays can also be hazardous to birds, either by direct contact or by feeding on the contaminated crop or seeds. Risks to feeding and nesting birds can be managed by:

- Minimising drift into bird habitats,
- Actively discouraging birds from feeding in crops which are to be sprayed,
- Spraying late in the day when birds have finished feeding,
- Using low toxicity pesticides.



## Pesticide fate processes

When a pesticide is mixed and applied, it is immediately subjected to numerous environmental forces that affect its fate. The behaviour and fate of pesticides in the environment should be a consideration when developing a farm PAMP, so that correct risk assessments can be made and appropriate management procedures established for each pesticide. Refer to Appendix 4 for more details of pesticide fate processes.

## 6.13 Residues

### Maximum Residue Limit (MRL)

The MRL is the highest concentration of a residue of a particular chemical that is legally permitted or accepted in a food or animal feed. The concentration is expressed in milligrams per kilogram (mg/kg) of the commodity. (Source: NRA website 2001)

### Withholding period (WHP)

The withholding period is the minimum time that must elapse between the last application of a pesticide to the crop, and the harvest, grazing and use of crop residues for consumption by humans or animals.

The withholding period is calculated from knowledge of the rate of degradation of the chemical under normal conditions, and assumes that the pesticide has been applied according to best management practices.

The WHP is an attempt to ensure that the pesticide residues do not exceed MRL.

The need to minimize residue levels is particularly important in export commodities (e.g. cotton and cotton seed), where an importing country may impose more stringent MRL limits than those in Australia.

**Remember:** Pesticides that drift off-target may contribute to residues in livestock and or native species that graze on the affected plants. As part of BMP, all growers must demonstrate due diligence to avoid off-target deposits of pesticides.

### Re-entry period

The period of time that must pass before an area that has been treated with a pesticide can be re-entered by humans without wearing protective clothing or equipment. Crop consultants can provide information on re-entry periods for specific pesticides and situations.



## 6.14 Disposal of containers and unused pesticides

### Reducing your pesticide and container disposal problem.

- Purchase pesticides in returnable, recyclable or soluble packaging.
- Plan spray applications properly.
- Use suppliers that provide product and packaging recovery programs such as drumMUSTER®, EnviroDrum® and Chemclear®. Discuss a return or exchange plan for chemicals that are not used immediately during the season.
- Use granules or dry flowable formulations in preference to liquids, and prepare the correct amount for each spray.
- Store the minimum quantities required.
- Minimise the amount of equipment used to handle and mix pesticides.

### Hazards - Disposal of pesticides and containers

Contamination	Environment, soil, water, air, personnel.
Degradation	Over time pesticides may degrade to form other compounds, packages may rust or decompose and labels may become unreadable.
Combustion	Disposal of containers and waste products in fires may produce toxic by-products or explosions that spread the contaminant over a wider area.
Misuse	If containers are not disposed of properly, they may end up being used for other purposes, such as water containers.

#### 6.14.1 How to properly rinse empty containers.

There are several methods of rinsing empty containers:

##### a) Probes and 'sucker flusher' transfer systems

Some chemical concentrate transfer systems include flushing facilities.

These systems typically involve connection of a probe to the container opening to extract the chemical concentrate. When the contents are removed a rinse cycle is activated. In all cases, the manufacturer's recommendations should be followed. Generally speaking, the rinse cycle should last at least 30 seconds.

Check the container thread and outside of the container and if contaminated, rinse with a hose into the spray tank. Rinse the cap separately in a bucket of water and pour this into the spray tank.



These systems have the advantage of significantly reducing exposure to the concentrate while transferring it to the spray tank.

## **Rinsing attachments**

Several spray equipment manufacturers supply a special rinsing attachment that enables drums and bags to be rinsed, by holding the container over a nozzle in the attachment and turning on the water. The rinsate is drained into the spray tank. The equipment manufacturer's recommendations should be followed. Generally speaking, the rinse cycle should last for at least 30 seconds.

### **b) Pressure rinsing (manual)**

A special nozzle designed to pierce the container is attached to the end of a hose to force the remaining product from the container. Pressure rinsing, which is generally faster and easier to carry out than manual triple rinsing, can be used with plastic and non-pressurised metal containers.

How to pressure rinse:

1. Remove the cap from the container. Empty the contents into the tank and allow draining for an extra 30 seconds after the flow reduces to drops.
2. Insert the pressure nozzle by puncturing through the lower side of the container.
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 (at least 30 seconds) or until the rinsate is clear. Rotate the nozzle 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 outside of the container and, if contaminated, rinse with a hose into the spray tank.
7. Let the container dry completely and replace the cap.

### **c) Triple rinsing (manual)**

Triple rinsing is a three-stage process.

1. Remove the cap from the container.
2. Empty the contents into the spray tank and allow the container to drain for 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.
6. Remove the cap. Pour the rinsate from the container into the sprayer tank. Let it drain for 30 seconds after the flow reduces to drops.
7. Repeat steps 2 to 6, two more times.



- .....
8. Check the container thread and outside of the container and if contaminated rinse with a hose into the spray tank. Rinse the cap separately in a bucket of water and pour this into the spray tank.
  9. Let the container dry completely and replace the cap.

## **Empty pesticide containers**

Proper management of used pesticide containers:

- ensures you get full value from the purchase,
- avoids visual pollution,
- protects the environment and prevents chemical residues from harming people, animals and wildlife,
- turns hazardous waste into acceptable landfill or a recyclable resource.

Before disposal, pesticide containers must be thoroughly rinsed. Rinsate can be disposed of by inclusion in a compatible registered spray mix or in a dedicated disposal pit.

### **6.14.2 Disposal of pesticide containers**

#### **Recycle**

Refer to the pesticide label for specific recommendations on disposal methods.

Where possible, purchase pesticides in returnable or recyclable containers (e.g. EnviroDrum®).

Large drums may be recycled through approved systems and/or the supplier.

Bulk handling containers should be returned to the pesticide manufacturer for refilling. Refer to the manufacturers recommendations.

#### **Disposal**

With metal, glass and moulded plastic containers, the following procedures should be adopted:

- After use, rinse the container properly, adding rinsate to the tank mix. Drums can contain minute amounts of pesticide even after triple rinsing and therefore should not be used for any other purpose.
- Then, pierce or crush the container. Drum crushers are available in some areas.
- Take crushed containers to an approved disposal facility.

Burning of paper containers is permissible only in places remote from people, livestock and public areas that could be affected by the smoke. Extreme care must be taken. It is also preferable to dispose of paper containers at designated local disposal areas (tips). Burning containers with residues of volatile herbicides must be avoided. If recycling (or the use of services such as drumMUSTER®) is not an option, dispose of plastic containers by delivering them to an approved disposal facility. Look for the drumMUSTER® logo on containers which qualify for collection in the program.



### 6.14.3 Disposal of pesticides

Pesticides should not be disposed of on the property. The following guidelines provide options for disposal of pesticide concentrates and mixtures.

Refer to the booklet *Aerial Spraying Facilities - Environmental Guidelines* (1998) produced by Cotton Australia, AAAA and EPA (NSW) and published by the EPA (NSW). This booklet has details regarding pesticide handling and disposal which are relevant to all applicators.

If pesticide applications are planned properly, and amounts are calculated correctly, then surplus concentrates and mixtures will be minimised.

#### Concentrates

- Return any unopened packages to the supplier or reseller.
- Store the pesticide in a secure store. Remember - Pesticides are required to have a shelf life of only two years.
- Arrange for collection by a waste contractor (Refer to 'Waste reduction and disposal services' in the Yellow Pages).
- Treat the pesticide so that it no longer poses a hazard to personnel or the environment. It may be possible to dispose of pesticides that rapidly biodegrade or hydrolyse in a correctly located and constructed disposal pit. (See Section 6.14.4)

#### ChemCollect®

A one-off government scheme for the collection of unwanted pesticides from properties. Once this scheme finishes, Chemclear® will commence collecting unwanted pesticide waste that is generated through current usage. Chemclear® will be funded by the pesticide supply industry.

Chemclear® will not collect unregistered pesticide waste or pesticides that are part of a manufacturers return scheme, so ChemCollect® will be the last chance to clear properties of unwanted pesticide concentrates.

#### Surplus pesticide mixtures

- Store the pesticide for later use. Pesticides that are stable after being mixed and are to be used in the next 12 hours could be left in the application tank with a warning sign attached (e.g. Poison, Hazardous Pesticide, Avoid Contact). Pesticides that will not be used in the next 12 hours should be stored in a holding tank with a warning sign and correct pesticide label attached.

Refer to the product label and ask resellers about the stability of pesticides after they have been mixed. Water quality and the chemical combinations in the mixture may affect the stability.

- Treat the pesticide so that it no longer poses a hazard to personnel or the environment. It may be possible to dispose of pesticide mixtures that rapidly biodegrade or hydrolyse in a correctly located and constructed disposal pit. (See Section 6.14.4)



## Contaminated pesticide waste

Pesticide wastes such as washings from cleaning application equipment, contaminated soil or rags, clothing or other personal protective equipment should be disposed of correctly. The following provides guidelines for the disposal of contaminated pesticide waste:

- Diluted liquid pesticide waste such as washings should be drained to a sump or evaporation pit.
- Solid waste such as contaminated soil or rags should be kept secure in a disposal drum with a secure lid. This disposal drum should then be disposed of in an approved manner.
- Consult with State Environmental Protection Agencies and pesticide suppliers for advice on correct disposal methods.
- Check with local landfill and disposal pit (tip) operators to see if they accept pesticide waste. If they will accept pesticide waste, it should be secured in a disposal drums and delivered to the disposal site. Correct safety precautions for pesticide transport should be followed at all times (Refer to Section 6.9).
- As a last resort, the contents of the drum may be disposed of on-farm in a suitable disposal site.

### 6.14.4 Establishing a disposal site on a property

On-farm disposal of pesticide waste is **not recommended**, and should only be undertaken as a last resort.

In Queensland, pesticide disposal sites on properties must be disclosed to future owners if the property is sold.

The site must be well maintained, marked, fenced and managed.

In NSW, contractors are not able to dispose of pesticide waste on the farm where the pesticide was used, nor on their own property. In Queensland, disposing of pesticide waste on-farm requires a licence. Contact the Queensland Environmental Protection Agency for more information.

Establishing a pesticide disposal site on a property may result in a contaminated site classification being applied to that area. Statutory requirements for contaminated sites vary, and should be carefully assessed prior to establishing a disposal area.

If an on-farm disposal site is necessary the minimum site specifications are:

- Level and above flood height,
- Of a suitable soil type to avoid excess ponding or leaching,
- Clear of water table high point,
- At least 50 m from roadways and the property boundary,
- At least 100 m from water courses, and not have drainage or seepage into water courses,
- The pit should be 1 to 1.5 metres deep and lined with clay or high density polyethylene (HDPE) sheeting,
- Add rocks and rubble to the pit to increase the surface area for bacteria to break down the chemical naturally,



- Adequately separated from houses, trees, livestock and crops,
- It should be fenced to exclude stock and unauthorised entry,
- The site should be clearly signposted with warning signs as a contaminated site. It should also be marked on farm maps.
- After adding residues, add lime and organic material if available to aid neutralization and breakdown of chemicals. Microorganisms to break down the waste may be available for purchase from pesticide resellers.

## 6.15 Pesticide spills

### 6.15.1 Dealing with spills

Even minor spills of pesticide need prompt action to minimise environmental contamination.

#### Hazards - Pesticide spills

Contamination	Environment, (eg. soil, water, air, flora, fauna). Personal or community contamination.
Flammability	Pesticides may be flammable or explosive.
Evaporation	Spilled pesticides may enter the atmosphere.
Corrosive action	Pesticides may be corrosive.

In addition to the directions on the pesticide label and MSDS, and information provided by the supplier, the following guidelines may assist:

- Wear suitable personal protective equipment (PPE).
- Control the spill by stopping the flow of pesticide. For example; stand a capsized drum in the upright position, place a broken container in a secure outer drum.
- Isolate the area and keep unauthorised people away, and marshal helpers (and other people) on the upwind side of the spill.
- Do not allow any smoking or naked flames near the spill area.
- Do not eat, drink or smoke during the clean-up operation and until personal decontamination is completed.
- Raise the alarm if necessary. Call the Fire Brigade and Police if the spill is in a public area and an Ambulance if personnel have been contaminated by the spill.
- Contain the spill to as small an area as possible by using sand or soil bunds. Do not allow the pesticide to drain into other areas or into waterways.
- Absorb liquid spills with soil, sand or another absorbent material.
- Prevent movement of solid pesticide spills by covering the area with tarpaulins or plastic.
- Decontaminate the affected area by applying hydrated lime, sweeping it thoroughly to cover all remaining pesticide residues and then shovelling the contaminated lime into disposal drums. Repeat until the area is clean.



- Clean up the spill by sweeping or shovelling the pesticide (and absorbent material) into disposal drums.
- If the spill occurs on soil, shovel up the affected soil and transfer it to disposal drums. Cover the affected area with a 5cm layer of hydrated lime and then finish with a layer of uncontaminated soil.
- All equipment which has been used should be decontaminated:
  - soak in a solution of bleach for 24 hours
  - wash in water and detergent
  - rinse and dry.
- Heavily contaminated equipment and clothing that cannot be cleaned should be placed in a disposal drum.

The Fire Brigade should handle major spills in a public place and after contacting them and the Police, priority should be given to keeping others away from possible chemical exposure until assistance arrives.

Refer to the pesticide supplier for disposal options once the clean up has been completed.

### Points to remember - Pesticide spills

<b>CARE</b>	- care for any personnel that may have been injured and/or contaminated.
<b>CLOTHING</b>	- ensure that all personnel involved in the clean up have PPE.
<b>CONTROL</b>	- the cause of the spill (e.g. return container to upright position). - access to the spill area by trained personnel.
<b>CONTAIN</b>	- the spill by surrounding it with soil, sand to prevent spread.
<b>CLEAN UP</b>	- with hydrated lime if available. This not only acts as a sponge but actively neutralises any organophosphates or carbamates present.
<b>COLLECT</b>	- the material, package in disposal drums and remove.

## 6.16 Spray failure

Good spray and crop records will assist to determine whether pesticide effectiveness has been reduced, or whether other factors have contributed. In the event of a suspected spray failure, contact relevant personnel (e.g. consultant, agronomist) and examine details of the application.

- Pest details - Pest levels before and after the spray, growth stages, resistance levels.
- Type of pesticide - Mode of action, formulation. Is it slower acting?
- Pesticide combinations and water quality.
- Crop factors (e.g. height, canopy density).
- Application conditions (e.g. wind, temperature, time of day).



- Application equipment. Is there 'striping' in effectiveness?
- Similar applications done on the same day.
- Post-spray conditions (e.g. rainfall, temperatures).
- Pesticide manufacture details - Batch number(s), date of manufacture, and identifying marks on the containers.

Make good notes of the findings and consult with the supplier. Don't respray with or use higher rates of the same product - rotate to another class of pesticides if possible. Seek independent assessments and advice.

## 6.17 Legislation

All personnel involved in the purchase, transport, storage and use of pesticides must be aware of their obligations under the applicable legislation. Growers should also be aware of common law provisions (Refer to your BMP manual).

Amendments to specific legislation should also be consulted.

Refer to your BMP manual for brief explanations of the following legislative documents:

### Commonwealth

Road Transport Reform (Dangerous Goods) Regulations (C'wealth) 1997.

### New South Wales

Contaminated Land Management Act (NSW) 1997.  
 Dangerous Goods Act (NSW) 1975.  
 Dangerous Goods (General) Regulation (NSW) 1999.  
 Occupational Health and Safety Act (NSW) 1983.  
 Occupational Health and Safety (Hazardous Substances) Regulation (NSW) 1996.  
 Pesticides Act (NSW) 1999.  
 Protection of the Environment Operations Act (NSW) 1997.  
 Road and Rail Transport (Dangerous Goods) Act (NSW) 1997.  
 Waste Minimisation and Management Act (NSW) 1995.

### Queensland

Chemical Usage (Agricultural and Veterinary) Control Act (Qld) 1988.  
 Environmental Protection Act (Qld) 1994.  
 Health Regulation (Qld) 1996.  
 Health (Drugs and Poisons) Regulation (Qld) 1996.  
 Workplace Health and Safety Act (Qld) 1995.  
 Workplace Health and Safety Regulation (Qld) 1997.  
 Workplace Health and Safety (Miscellaneous) Regulation (Qld) 1995.

### Codes of Practice

Commonwealth	Australian Dangerous Goods Code.
New South Wales	Code of Practice for the Safe Use and Storage of Chemicals in Agriculture.
Queensland	The Storage and Use of Chemicals at Rural Workplaces - Industry Code of Practice.



## 7. Spray equipment

### Hazards - Application equipment

Drift	Using incorrect techniques, poorly maintained or inappropriate equipment or spraying in sub-optimal weather conditions may lead to spray drift and off target contamination.
Equipment	Use of incorrect equipment or configuration for spraying may increase the risk of injury or damage.
Outlet type	Incorrect spray outlets (nozzles) selection may lead to incorrect dosage, sub-optimal coverage or increased drift potential.
Calibration	Incorrect calibration may lead to incorrect application rates and/or reduced pesticide efficacy, or extended residues in the crop.
Maintenance	Poor maintenance may lead to equipment failure, pesticide spillage and personal contamination.
Safety	Failure to observe safety and BMP guidelines during loading, spraying, unloading and decontamination may lead to accidents, personal injury or death.

### 7.1 Ground application

#### Types of ground rigs

- Three point linkage,
- Trailed,
- Self propelled.



Photo: Hardi Spraying Equipment Pty. Ltd.



Photo: GoldAcres Sprayers



Photo: Spray Coupe



There are four main types of ground application sprayers used in cotton:-

- Conventional hydraulic boom sprayer,
- Air-assisted boom sprayers,
- Controlled droplet applicator or 'CDA' sprayers,
- Air shear boom sprayers.

## Hydraulic boom sprayers

Hydraulic pressure is the most common method of applying pesticides, and is used on a range of equipment due to its simplicity and flexibility. To produce droplets, liquid is forced under pressure through a small specially designed hole (orifice). A thin sheet of liquid is formed which then becomes unstable and disintegrates into spray droplets (Refer to Section 7.4).

However, due to the uncontrolled nature of the disintegration, a range of droplet sizes is produced. The droplet sizes that are produced depend on the pressure, orifice size and orifice design. Flow rate depends on orifice size and pressure. Refer to Section 7.4 for more information on nozzles.

*Advantages:*

- Components are relatively simple.
- Equipment can be tailored to individual situation, i.e. row width.
- Requires simple changes in operating parameters (i.e. nozzle type, pressure) to change between herbicides and insecticides, or to change for varying conditions.
- Range of droplet sizes may give a 'shotgun' approach for a range of targets.

*Disadvantages:*

- Nozzles will wear, and so require regular replacement.
- The wide spectrum of droplet sizes may result in droplet wastage due to drift of small droplets and runoff of large droplets.

*In general droplet size decreases when:*

- orifice size decreases,
- pressure increases,
- fan angle increases.



## Air assisted boom sprayers

This system utilises a slower air stream to carry droplets generated by either hydraulic pressure or CDA towards a target, and then to replace the air surrounding the target with the chemically charged volume. Generally, large volumes of slow moving air are involved, but recent design has seen the use of increased turbulence to improve canopy penetration and underleaf coverage.

Air-assist sprayers may reduce drift by up to 50% compared to a conventional boomsprayer operating under similar conditions. However, manufacturer recommendations should be followed, particularly with reference to the flow rates and air speed set-up.

**Fig. 7.1. Hardy 'Twin Stream®' air assist boom.**



Photo: Hardy

## Controlled droplet application (CDA)

Most commercial CDA ground rig sprayers use centrifugal energy for droplet production.

Liquid is fed onto a spinning disc, cage or drum and the centrifugal energy spreads the liquid to the edge where it breaks up first into liquid ligaments, which in turn break into droplets (Refer to Section 7.4). The system is capable of producing a narrow range of droplet sizes providing the liquid flow rate and rotational speed of the disc are matched. Smaller droplet sizes are produced as disc or cage rotation speed increases. If the flow rate is too high for the rotation speed, a wide range of droplet sizes is produced.

**Fig. 7.2. Micromaster® CDA applicator.**



Photo: Peter Hughes

### *Advantages:*

- Application volumes can be decreased due to the narrow droplet spectrum.
- Increased proportion of droplets of optimum size.
- A narrow range of droplets can be produced (compared to hydraulic nozzles).

### *Disadvantages:*

- Increased expertise required to set up and operate.
- Possible mechanical failure due to more complex system ( i.e. hydraulic or electric



motors, discs or cages).

- Not suited to banded applications unless fitted with additional hydraulic nozzles and droppers.

*In general, droplet size decreases when:*

- flow rate decreases,
- rotation speed increases.

### **Air shear sprayers**

Droplet production with these machines depends on the impact of a column of high velocity air (at least 300 kph) on a stream of liquid. The liquid is shattered and the air stream is used to propel the resultant droplets towards the target. They are commonly used to apply insecticides and fungicides. They are not recommended for herbicide application, because of the very fine droplet spectrum.

Due to the high air velocity, care must be taken when setting up and operating the equipment. Air stream 'bounce' and plant damage can be a problem when plants are small. Droplet size can be manipulated by altering the flow rate of the pesticide and the air flow rate.

**Fig. 7.3. Silvan 'Magnum Airboom®' air shear sprayer**

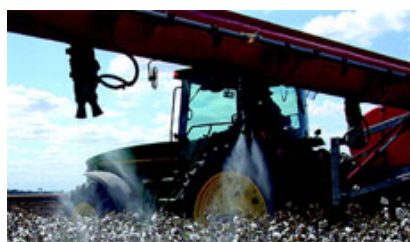


Photo: Paul Kleinmeulman

*Advantages:*

- Produces fine and very fine droplet spectrum (for coverage).
- Increased proportion of droplets of optimum size.
- A narrow range of droplets can be produced (compared to hydraulic nozzles).

*Disadvantages:*

- Fine and very fine droplet spectrum may increase risk of off-target movement.
- Not suited for herbicide application.
- Not suited to banded applications unless fitted with additional hydraulic nozzles and droppers.

*To make droplets smaller*

- increase air speed,
- lower pesticide flow rate.

*To make droplets larger*

- run blower engine at reduced throttle (Note: If the airspeed is reduced too much, a very poor droplet spectrum results),
- increase liquid flow rate.



## 7.1.1 Groundrig nozzles

Refer to Section 7.4 for more detailed nozzle information.

### Hydraulic nozzles

Hydraulic nozzles are the most frequently used nozzles for ground rig applications. Nozzles that are used include flat fans, hollow cones and flood types. The number of nozzles and configurations vary widely and depend on the stage of crop and target being sprayed. There are an increasing number of innovative nozzle designs available on the market which are specifically designed to reduce drift. These should be evaluated by ground rig operators (as part of the BMP process) and fitted if they are cost-effective and result in better spraying. New nozzle designs are constantly being released to the market, and spray equipment suppliers and manufacturers should be consulted on the latest developments.

### Centrifugal Energy (CE) nozzles

CE units have been used on groundrigs but there are only a very small number in operation compared to hydraulic boom sprays. The ground based CE sprayers utilise CE units similar to the aerial units, or spinning discs, but the units are powered by hydraulic or electric motors. These are generally custom built spray boom configurations.

### Guidelines for ground spraying

- Develop a PAMP before the season starts.
- Communicate with neighbours and all personnel involved.
- Ensure that personnel are properly trained to handle, mix and apply pesticides safely.
- Use nozzle tables to select pressures and droplet sizes (Refer to Sections 7.4. and 7.5).
- Check equipment and calibrate at regular intervals.
- Keep a sprayer maintenance kit for in-field maintenance.
- Boom height should be as low as possible to achieve optimum spray pattern.
- Consider the use of wide angle (e.g. 110°) for lower boom heights and less drift.
- Where applicable use droppers and/or specialised nozzles to improve coverage and reduce drift.
- Vertical boom movement should not exceed 0.5m whilst spraying.
- Monitor weather conditions and be prepared to delay or abort the operation if conditions become unsuitable for safe spraying.
- Decontaminate and wash down equipment after each job.
- Maintain proper spray and PAMP (BMP) records.



## 7.1.2 Equipment set-up summaries - Ground rigs

Equipment manufacturer specifications and recommendations should be followed.

The following tables provide set-up details for various pesticides, application situations and equipment.

The lists are not comprehensive, and are intended only as a reference guide.

**Table 7.4. Set-up guide for groundrig sprayers fitted with hydraulic nozzles.**

Hydraulic boom						
Crop stage	Prod. type	Nozzle	Press. (KPa)	Boom Config.	Vol. (Lt per sprayed Ha)	Notes
Preplant	Contact herbicide	Flat fan 015 / 01	300	Broadacre	40 - 60	Check nozzle overlap.
		Lo drift	300	Broadacre	50 - 70	
		Low pressure	150	Broadacre	60 - 80	
	Residual herbicide	Flat fan 03 / 04	250-300	Broadacre	80-250	Check nozzle overlap.
		Low drift 03 / 04	300	Broadacre	80-250	
		Low pressure	150	Broadacre	80-250	
At planting	Contact or residual herbicides	Even fan 03	300	Band behind planter	80-250	Set height for correct band width. Higher volumes preferred.
		Even fan 04	300		80-250	
	Water injection	Not applicable	N/A	Planting boot	650 -1200	Insecticide or fertiliser may be included. High volumes result in lower field efficiency.
In crop	Directed spray - herbicides	Flat fan 02 / 03	250-300	Directed band according to weeds and crop stage	50-70	Nozzle height and position critical to ensure that crop is not sprayed. Use flat fan nozzles where two sprays overlap.
		Low pressure 02	150		60-80	
		Low pressure 03	250-300		55-70	
		Low drift 02 / 03	250-300		55-70	
		Even fan	150-300		50-70	
	Shielded spray - herbicides	Flat fan 02 / 03	250-300	Band according to weeds.	50-70	Complete nozzle hoods preferred to prevent drift. Increase spray volumes to maintain coverage and reduce pressures where possible.
		Low pressure 02	150		60-80	
		Low drift 02	250-300		60-80	
		Even fan 02 / 03	150-300		50-70	
	Insecticides 0 - 30% band	Flat fan 01, 015, 02 (incl. low drift types)	>300 Refer to charts	1/row 1-2/row	40-160	If multiple nozzles per row, make sure pattern overlaps before spray hits crop.
	Insecticides 30% - 50% band	Flat fan 01, 015, 02 (incl. low drift types)	>300 Refer to charts	3/row 3/row	70-160	If multiple nozzles per row, make sure pattern overlaps before spray hits crop.
	Insecticides 50% band - Full cover.	Flat fan 01, 015, 02 (incl. low drift types)	>300 Refer to charts	3/row 5/row	70-160	If multiple nozzles per row, make sure pattern overlaps before spray hits crop.
Harvest prep.	Defoliant	Flat fan 110° -02 Hollow cone TX8	>500 >500	3/row 5/row	100-200 100-200	Make sure pattern overlaps before spray hits crop.



**Table 7.5. Set-up guide for groundrig air assist type sprayers.**

Air assist boom						
Crop stage	Prod. type	Nozzle	Press. (KPa)	Boom Config.	Vol. (Lts per sprayed Ha)	Notes
Preplant	Contact herbicide	Flat fan 110° 015 / 01	300	Broadacre	40 - 60	Decrease air volume. Ensure that air stream does not bounce off ground surface.
	Residual herbicide	Flat fan 110° 03 / 04 Low drift 03 / 04 Low pressure	250-300 300 150	Broadacre Broadacre Broadacre	80-250 80-250 80-250	No air or very low setting. Make sure you cannot feel air bouncing at ground level.
At planting	Contact or residual herbicides	N/A	N/A	N/A	N/A	N/A
In crop	Insecticides 0 - 30% band	Flat fan 02 Hollow cone TX8	>500 >500	1 outlet/row	30-50	Aim outlet across and down at the row.
	Insecticides 30% - 50% band	Flat fan 02 Hollow cone TX8	>500 >500	1 outlet/row	30-50	Increase air volume.
	Insecticides 50% band - Full cover.	Flat fan 02 Hollow cone TX8	>500 >500	1 outlet/row	30-60	High air volume. Aim outlet slightly across and down at the row. Allow pattern to spread out before hitting the crop.
Harvest prep.	Defoliant	Flat fan 110° -02 Hollow cone TX8	>500 >500	Minimum 1 outlet/row	70-140	Use the highest volume at lowest airspeed.

**Table 7.6. Set-up guide for groundrig airshear sprayers.**

Air shear sprayer						
Crop stage	Prod. type	Nozzle	Press. (KPa)	Boom Config.	Vol. (Lts per sprayed Ha)	Notes
Preplant	Contact herbicide	N/A	N/A	N/A	N/A	Not recommended
	Residual herbicide	N/A	N/A	N/A	N/A	Not recommended
At planting	Contact or residual herbicides	N/A	N/A	N/A	N/A	N/A
In crop	Herbicides	N/A	N/A	N/A	N/A	Not recommended
	Insecticides 0 - 30% band	N/A	N/A	1 outlet/row	40-80	Direct outlet 45° to the row. Requires hydraulic nozzles to band
	Insecticides 30% - 50% band	N/A	N/A	1 outlet/row	40-80	Direct outlet 45° to the row. Requires hydraulic nozzles to band
	Insecticides 50% band - Full cover.	N/A	N/A	1 outlet/row	40-80	Direct outlet 45° to the row. Requires hydraulic nozzles to band
Harvest prep.	Defoliant	N/A	N/A	1 outlet/row	70-140	At least one outlet per row.



Table 7.7. Set-up guide for groundrig sprayers fitted with CDA nozzles.

CDA sprayer						
Crop stage	Prod. type	Nozzle	Press. (KPa)	Boom Config.	Vol.(Lts per sprayed Ha)	Notes
Preplant	Contact herbicide	CDA	-	Broadacre	50-60	Specific CDA units will work on broadacre.
	Residual herbicide	CDA	-	Broadacre Large droplets.	80-100	Specific CDA units will work on broadacre.
At planting	Contact or residual herbicides	N/A	N/A	N/A	N/A	N/A
In crop	Herbicides	N/A	N/A	N/A	N/A	Not recommended
	Insecticides 0 - 30% band	N/A	N/A	1 outlet/row	20	Direct outlet 45° to the row. Requires hydraulic nozzles to band
	Insecticides 30% - 50% band	N/A	N/A	1 outlet/row	20	Direct outlet 45° to the row. Requires hydraulic nozzles to band
	Insecticides 50% band - Full cover.	N/A	N/A	1 or more outlets/row	20	Direct outlet 45° to the row. Requires hydraulic nozzles to band
Harvest prep.	Defoliants	N/A	N/A	1 outlet/row	40-80	Ensure that flow rate is not too great for CDA units.

Pesticide labels may have specific recommendations with regard to ground application.

Example 1: The Thiodan EC® label (2002) included the following recommendations:

### Mandatory

Do not apply endosulfan EC formulations unless a volume of carrier water greater than 50 L/ha is used. For band spraying applications, use at least 50 L/ha of carrier water for the actual area sprayed in the bands.

Use only flat fan nozzles with all ground-based boom sprayer equipment.

All nozzles must be operated such that a “medium” spray quality is produced as indicated by manufacturers according to the BCPC and ASAE nozzle classification system.

Do not use additional adjuvants in the spray mix unless approved (on label) by the pesticide manufacturer.

Do not use ducted air or sleeve sprayers unless the air velocity is adjusted to ensure that there is no reflection of air from the ground surface.

### Advisory

Release height of the spray should be as low as possible, consistent with nozzle specifications and coverage requirements. Boom sprayers should be rigged to ensure that vertical boom movement does not exceed 0.5 metres at normal operating speeds.



Example 2: The Steward® label (2002) contains the following specific recommendations:

### Application

Application equipment should be calibrated to apply at least sixty (60) droplets per cm<sup>2</sup> of target cotton foliage. Droplet VMD should be in the range of 150-250 microns.

### Ground application

Apply either as a blanket spray or a banded spray over the cotton plants. Apply in a minimum spray volume of 100L/ha. Ensure thorough spray coverage on the cotton foliage. This can be maximised by using appropriate sized hollow cone nozzles to deliver 100L spray volume per hectare. Increase the number of hollow cone nozzles per cotton row as the plant size increases. A minimum spray pressure of 275 kPa (40psi) should be used with hollow cone nozzles. **Higher pressure reduces droplet size, DOES NOT improve canopy penetration and may increase drift potential.**

WHEN HIGHER FLOW RATES ARE NEEDED, USE A HIGHER-CAPACITY NOZZLE INSTEAD OF INCREASING PRESSURE.



Photo: Groundrig Operators Association Inc.



## 7.2 Aerial application

The use of agricultural aircraft in cotton has developed largely as a result of the greater speed, better timing and flexibility of application.

Aircraft are able to apply agricultural products rapidly over large areas within narrow application windows. When crop height and recently irrigated areas restrict the passage of ground based spray rigs, aircraft are able to apply pesticides onto crops without contributing to soil compaction.

### Fixed wing aircraft

Depending on location, different types of aircraft are used in the cotton industry.

Medium sized aircraft include the Cessna AgTruck (AgHuskey) and Piper Pawnee Brave. These aircraft are fitted with 400 HP air cooled engines, and can lift about 1000 kg of material.

Where high utilisation can be obtained over extensive cotton growing areas, larger 600 HP Air Tractor and Ayres Thrush fitted with large radial piston engines can be used.

However, there has been a steady trend towards the turbine powered aircraft. Using essentially the same airframe, Air Tractors and Thrushs fitted with small powerful turbines are now common place in most cotton growing areas. Turbine engines are lighter and more powerful than equivalent piston engines, turn 3 and 5 bladed propellers and generally have lower direct operating costs. Capable of lifting in excess of 2 tonnes of product these aircraft are the 'quiet achievers' of the aerial agricultural industry.

Considerations when using fixed wing aircraft for spraying include:

- Total application volume and droplet size should be selected to suit the type of spraying (LDP, LV or ULV), target and pesticide.
- Similarly, equipment and nozzle selection should be optimised for the type of spraying, target and pesticide.
- Production of very small droplets should be avoided.
- The aircraft should be set-up to minimise the effect of wing tip vortices.
- Nozzles and/or outlets should be shut off within the target area and before climbing.
- The flight pattern should be planned to ensure an even distribution over the area being sprayed.
- Aircraft should be flat and level during application.



Photo: Spray Drift Task Force (USA).



- Turning over residential and public areas should be avoided and noise minimised.
- Nozzle (outlet) height should be approximately 3 metres above the crop unless the aircraft set-up or product label has specific requirements.
- Spray in a crosswind under neutral atmospheric conditions. Avoid spraying in strongly unstable conditions.
- The operator should monitor meteorological conditions during the application and delay or abort the job if conditions become unsuitable.
- The grower should maintain communication with the pilot to relay information on conditions on the ground and any unforeseen changes.
- All applications should follow procedures that were established as part of the property pesticide application management plan (PAMP) which was prepared pre-season.

For more information refer to “Operation Spray Safe - Pilots and Operators Manual” 2nd Edition (1997) produced by the Aerial Agricultural Association of Australia Ltd.

## Helicopters

Helicopters are suited to a niche in the aerial application market, due to their manoeuvrability and ability to land without requiring an airstrip. However, they are generally slower than fixed wing aircraft, carry smaller loads and are more expensive per hectare to operate.

In addition to the general guidelines for the aerial application of pesticides (outlined in the previous section), there are important considerations that are specific to helicopters.

Unlike the wings of fixed wing aircraft, rotor blades allow a helicopter to perform a wider range of functions. Each of these functions requires different settings and speeds of the rotor blades so the air patterns around the helicopter vary considerably, and must be considered during pesticide spraying.

When a helicopter hovers, the maximum downwards air flows (downwash) occurs at a point about 85% out from the centre of the rotors, with slower moving air near the centre. Heavier helicopters tend to produce significantly greater downwash velocities.

As the helicopter moves forward (as a result of tilting the rotor disc), the downwash beneath the machine decreases, and the rotor tips create downwash and a vortex which ‘rolls up’ behind the aircraft. At about 40 km/hr the air flow pattern produced resembles that of a fixed wing aircraft. Because most spraying is carried out at speeds greater than 40 km/hr, the pesticide applications will be similar to fixed wing aircraft in similar operating environments.



Photo: 4T



Helicopters may be able to operate at slower speeds to produce coarser (larger) droplets than fixed wing aircraft fitted with the same equipment.

General points that are relevant to helicopter application:

- Spray application should not be carried out while the helicopter is in the hover position.
- Spray booms should not extend beyond the diameter of the rotor disc.
- Spray penetration of the crop canopy can be achieved using the downwash from the rotor, provided the boom set-up is correct and the forward speed does not exceed about 40 km/hr.
- Placement spraying of pesticides using helicopters is usually achieved by using coarse droplets ( $>250\ \mu\text{m}$ ) and moderate forward speeds.
- Rear and mid mounted booms will place spray into the high velocity part of the rotor wake.
- If helicopter spraying is planned, specific sections may need to be added to the PAMP plan, such as helipad and loading positions, and specific flight instructions.

### **Advantages of using aircraft for pesticide application**

- Aircraft can be used over wet areas which may be impassable to a wheeled vehicle.
- Soil compaction and wheel marks are eliminated.
- Faster and more fuel efficient.
- Greater area treated during optimal application windows.
- Aircraft minimise the risk of transmitting soil borne diseases.
- Grower labour is reduced.
- Aircraft still operate when crop height restricts use of ground rigs.

### **Disadvantages of using aircraft for pesticide application**

- Aeroplanes and helicopters are visible and audible - they attract attention and may cause noise pollution.
- In general, aircraft release pesticides higher above the crop than ground rigs - this may increase drift potential. It may also increase the evaporation losses of some water based products.
- Low flying and obstacles pose significant risks for agricultural pilots.
- May be more expensive than ground based spraying.
- Small cotton fields and those surrounded by hazards may not be able to be treated effectively.
- Application 'windows' for optimum spray (and flight) conditions may be shorter than for ground rigs.



## 7.2.1 Aircraft nozzles

Refer to Section 7.2 for more detailed nozzle information. Cotton insecticides, herbicides and defoliants are applied to cotton using both hydraulic nozzles and centrifugal energy nozzles (CE).

### Hydraulic nozzles

Hydraulic nozzles such as hollow cones, large orifice flat fans and the CP® variable flow rate solid cone nozzles are used on aircraft. An aerial operator will normally set up an aircraft with about 20 to 50 hydraulic nozzles depending upon nozzle type, required flow rate and the need to balance the spray pattern underneath the aircraft to counteract the influence of the airflows about the airframe. Refer to section 7.3.3 for descriptions of these nozzles.

In general, larger droplets are capable of being generated by hydraulic nozzles (250 – 500 µm). The actual droplet size produced is highly dependent upon the angle at which the nozzles are set relative to the airstream and airspeed. When nozzles are angled down and then forward into the airstream, progressively smaller droplets are created as the relative velocity between the liquid and airflow is increased, similar to the effect obtained with an air shear nozzle in a misting machine.

### Centrifugal Energy (CE) nozzles

Unlike hydraulic nozzles, which rely on liquid pressure to break the pesticide stream into droplets, CE nozzles use centrifugal energy to pass liquid through a rotating gauze (or cage) which breaks the liquid stream into droplets. There are a number of CE units available in Australia but the most popular is the Micronair AU5000®. The droplets are formed as the liquid flows firstly through a diffuser tube and then out through a rotating cylindrical gauze cage. The cage is driven by small propeller blades and rotates at 2,000 to 10,000 RPM. The liquid flow into each unit is controlled by a variable restrictor unit (VRU).

The Micronair AU5000® has been widely adopted in Australia due to the ability to change the size of the droplets it emits, and the ease with which it handles most agricultural formulations. Droplets generated by the Micronair AU5000® are generally less than 250 µm (VMD), which makes the unit very suited to both low volume (LV) and ultra low volume (ULV) insecticide application. These outlets are commonly referred to as ‘micronairs’.

Aircraft are normally equipped with 8 to 12 units. Faster aircraft will need the higher number of units to apply rates greater than 30 L/ha. Each micronair unit should be fitted with tachometers so that cage rotation speed can be monitored by the pilot.

### Spreaders

Solid formulations of fertilisers can also be applied by air by means of gravity fed ram-air spreaders to distribute the material evenly over the ground. As with liquid spray application, it is important that the correct flight-lane separation is adopted to obtain the most even deposit across the paddock and generate the correct application rate in terms of litres or kilograms per hectare.



## 7.2.2 Aircraft set-up

Individual operations require specific equipment and nozzle configurations. The main points to consider are listed in this section, but for more detailed information refer to “Operation Spray Safe - Pilots and Operators Manual”, AAAA, manufacturers technical specifications and/or experienced aerial operators in cotton growing areas.

### Nozzles

The type of nozzles should be selected for compatibility with the aircraft configuration. Refer to nozzle performance charts and manufacturers recommendations for installing and setting nozzles for specific situations. Different types of nozzles and outlets are summarized in Section 7.4.

In all cases, flight speed will affect the droplet spectra by increasing or decreasing the air shear effects and rotation speeds of centrifugal outlets. Flow rates and application rates must be accurately calibrated for each nozzle configuration. Hydraulic nozzles can be angled to the airstream to produce different air shear, which affects droplet size and spectra. Nozzles that are orientated at 180° to the airstream (facing backwards on the aircraft) will produce larger droplets than the same nozzles angled at 45° (facing forwards) to the airstream. Different nozzle angles across the boom may improve deposition and reduce vortex effects. Similarly, the blade angle of Micronairs® can be altered to change cage rotation speed which affects droplet size. Smaller droplets are produced as cage rotation speed increases.

Flow metering, loading and application equipment must be maintained properly so that application is optimised and downtime is minimised.

Adverse effects on spray patterns due to vortices can be minimised by:

- Designing boom width so that it does not exceed 65% of wingspan (fixed wing) or rotor wing (helicopters).
- Mounting the boom at least 25 cm below the trailing edge of the wing.
- Selecting larger droplet sizes on the outermost nozzles or outlets. This can be achieved by selecting larger nozzles, angling hydraulic nozzles at 180° to the airstream or altering the blade angle of Micronair® units.
- Ensuring that the aircraft is flat and level over the crop before spraying starts.
- Testing application patterns and altering configurations to ensure even coverage.

There are additional factors to be considered when using helicopters:

- Spray penetration can be achieved using the downwash of the rotor at airspeeds less than about 40 km/hr. If this technique is used, the boom and nozzle configuration should be altered accordingly.
- As forward speed is increased the spray deposit becomes asymmetric under the influence of the differential vortex pattern. This can be corrected by using an asymmetric configuration of nozzles on the spray boom, such as putting a greater number of nozzles on one side of the boom.
- Positioning of the boom can be critical to avoid undesirable downwash or wake patterns.



Refer to product labels for specific aircraft set-up recommendations.

Example 1: The Thiodan EC® label (2002) contains the following specific recommendations:

NOTE WELL: All nozzles must be directed backward and aimed parallel with the airstream		
Nozzle type	Airspeed 90 - 115 knots	Airspeed 116 - 135
CP® Standard 30° deflector	✓ Boom pressure greater than 30 psi required	DO NOT USE
CP® Straight stream 30° deflector	✓	DO NOT USE
CP® Straight stream 5° deflector	✓	DO NOT USE
CP® Straight stream 5° deflector	✓	✓ Boom pressure greater than 30 psi required.
Flat fan Min. Specification: Fan angle 65° or less. Orifice size 10 or greater	✓	✓

Source: Bayer Thiodan®/EC label.

Example 2: The Steward® label (2002) contains the following specific recommendations:

<p><b>Application</b></p> <p>Application equipment should be calibrated to apply at least sixty (60) droplets per cm<sup>2</sup> of target cotton foliage. Droplet VMD should be in the range of 150-250 microns.</p> <p><b>Aerial application</b></p> <p>Steward® must only be applied with aircraft fitted with accurately calibrated equipment. Apply a minimum total spray volume of 30L/ha with either Micronair® rotary atomisers or conventional hydraulic nozzles set to spray droplets with a VMD in the range of 150-250 microns. A strategy as per the cotton industry's Best Practice Manual should be employed at all times to minimise spray drift during aerial application. <b>DO NOT apply Steward® using Ultra Low Volume (ULV) methods.</b></p>
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Source: DuPont Steward® label.



### 7.2.3 Aerial application methods

Table 7.8 shows a summary of the main aircraft application methods that are used in cotton in Australia.

Table 7.8. Main aerial application methods.

Aerial application methods						
Solids	Liquids					
-	ULV	LV			LDP	HV
	2 - 5 L/ha	20 - 30 L/ha	10 - 30 L/ha	20 - 30 L/ha	30 - 50L/ha	40 - 100 L/ha
Fertilizer Herbicides Insecticides	Insecticides	Fungicide	Insecticide	Herbicide	Herbicide Insecticide	Fungicide Herbicide

Ultra low volume (ULV)

- insecticides in immature cotton
- insecticides in mature cotton

Low volume (LV)

- herbicides
- insecticides (e.g. EC formulations)

Large droplet placement (LDP)

- herbicides
- insecticides (e.g. EC formulations)

High volume (HV)

- seldom used due to ferrying and refilling costs
- herbicides

The application method used for an application will depend on the pest type, pesticide formulation and operating conditions at the time of application. High volume spraying is now seldom used and is not discussed in detail in this handbook.

Definition: *Volume Median Diameter (VMD) - Within the spray plume, 50% of the spray volume consists of droplets smaller than the value indicated. Refer to Section 7.5.4 for a more detailed explanation of VMD.*

#### Ultra low volume (ULV) spraying

*Very fine droplets (<100µm VMD) applied at rates of less than 5 L/ha.*

ULV insecticide sprays are often applied in cotton using the mechanical wind generated turbulence above the crop canopy to distribute the droplets about the target. Pesticides formulated in oil based (low volatile) carriers are applied undiluted at total application rates of 2–5 L/ha. This low rate of carrier is achieved by generating very fine droplets (about 50–100 µm VMD). Such droplet sizes allow large numbers of droplets to be generated thereby compensating for the low volume of carrier. ULV spraying can be highly efficient and lead to decreased application costs due to fewer takeoffs and landings and less ferrying time being required per litre volume applied.

ULV application can have a significantly greater drift potential than LV or LDP applications.



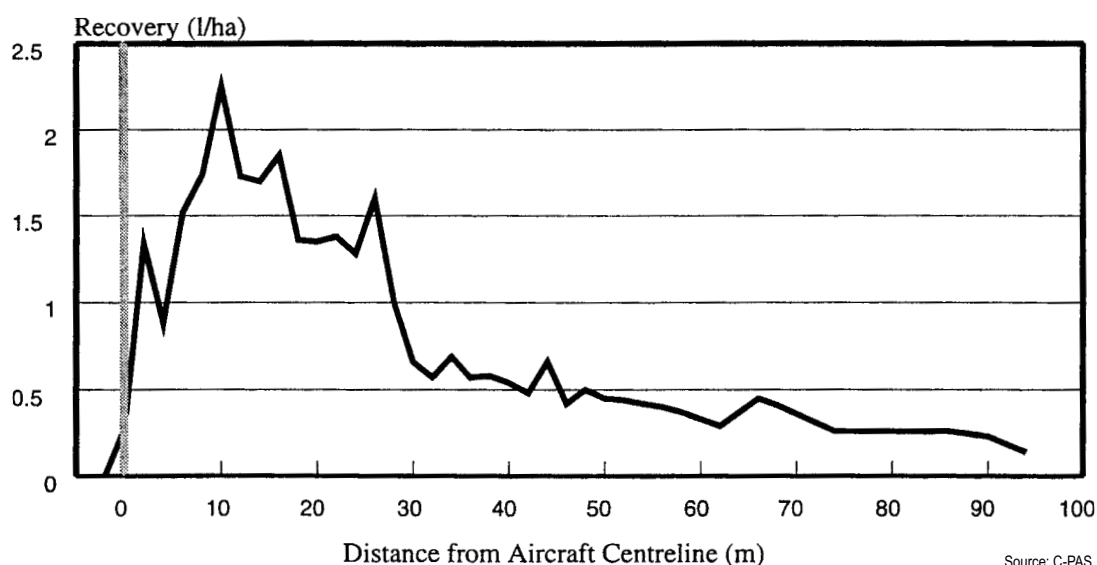
Since a prevailing wind moves mainly horizontally across the top of a crop, fine droplets with their low sedimentation velocity are transported towards the crop surface at low angles and therefore tend to impact on vertical surfaces such as cotton terminals.

It is often assumed that in a wind all the fine droplets contained in a spray cloud will be blown huge distances downwind. However, if application is undertaken such that mechanical turbulence is being generated in a neutral atmosphere, the peak pesticide deposit in the crop is often located within 20 metres of the line of flight of an aircraft. This is because the droplet cloud is expanded by the turbulence and brought quickly towards the ground.

However, although the peak deposit is often close to the release point, a 'tail' of fine droplets can be carried significant distances in some circumstances and such application technology should not be used where there are susceptible areas located downwind of the cotton paddock.

Figure 7.9 shows a ULV deposit pattern recovered by using fluorometry from the top canopy of a mature cotton crop. A single application run of Larvin® LV was applied to the cotton in a 90° cross wind at 5 L/ha using an Ayres turbine Thrush aircraft fitted with 10 Micronair AU5000® units. The droplet spectra (size range) was measured in the laboratory prior to the experiment and found to have a VMD of 90 µm. A small quantity of UV fluorescent tracer was added to the pesticide mixture and subsequently illuminated on the leaf surfaces after application to show the deposit pattern. Although the wind speed was 2.6 m/s (9.4 km/hr) the peak insecticide deposit was located about 10 metres from the flight line. The downwind tail of droplets is clearly shown. Such patterns can also be overlapped using computers to determine optimum flight lane separation and deposit data.

Fig. 7.9. Typical droplet deposition pattern - Aircraft fitted with AU5000® micronairs.



## Low volume (LV) spraying

*Fine droplets (100 - 250µm VMD) applied at rates of 5 to 30 L/ha.*

Larger droplets have greater kinetic energy and fall towards the ground under the influence of gravity at higher terminal or sedimentation velocities. Since larger droplets fall relatively fast towards the ground and are not greatly influenced by vertical air movement and turbulence, their trajectory can be calculated with reasonable accuracy.



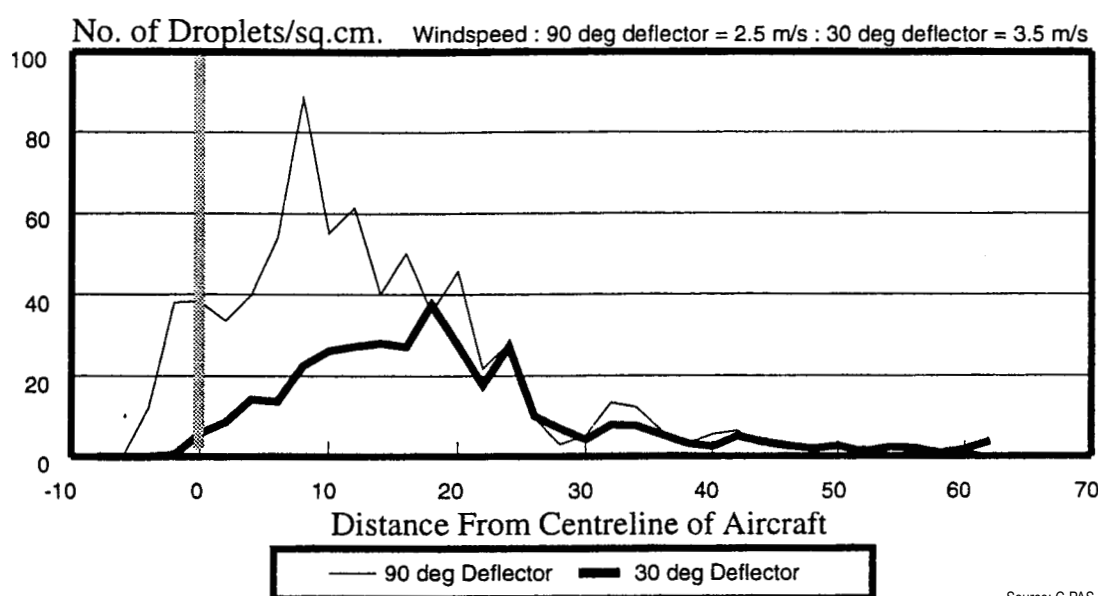
Generally LV spraying is undertaken using EC or DF formulations using total application rates of water between 20 and 30 L/ha. Herbicides may be applied using LV techniques, but care must be taken if smaller droplets and lower volumes are being used. Optimal conditions for LV application of cotton insecticides, to minimise drift, are light winds with low temperatures ( $<28^{\circ}\text{C}$ ) and high relative humidity ( $>65\%$ ). This type of application is used primarily to cover the upper canopies of crops, prostrate plants (weeds) and soil (pre-emergent herbicide application). This method is also used for the application of most defoliant.

When LV spraying is used, aerial operators sometimes attempt to generate slightly smaller droplets in order to increase the number deposited per unit area and thus increase the chances of contacting small moving targets. However it is important in this situation that application is undertaken under cool, moist conditions and in a neutral atmosphere (see Section 3) to prevent excessive evaporation.

Figure 7.10 shows a typical placement deposit pattern generated by an agricultural aircraft fitted with hydraulic (CP®) nozzles. Two patterns are drawn showing the number of droplets deposited on flat horizontal artificial targets using CP® nozzles with the deflector plates angled at  $30^{\circ}$  and then  $90^{\circ}$ . The graph shows clearly that a larger number of droplets were deposited when the  $90^{\circ}$  deflector plate was used. This is because the larger angle caused the spray to be diverted into the airstream, breaking the liquid into smaller droplets. The smaller droplet size has resulted in a greater number of droplets being deposited.

Larger droplets may be deposited more evenly across the ground if a flight lane separation is adopted that allows the pattern to be overlapped across a paddock to give a uniform deposit. Specialists in aerial application (e.g. C-PAS) routinely conduct tests for aerial operators to establish optimum flight lane separation (FLS) values and deposit levels for specific aircraft and nozzle systems.

Fig. 7.10. Typical droplet deposition pattern - Aircraft fitted with CP® nozzles.



## Large droplet placement (LDP) spraying

*Medium to coarse droplets (>250µm VMD) applied at rates greater than 30 L/ha.*

If medium to coarse droplets are produced by the aircraft with the aim of laying down a uniform deposit over the surface of a crop, this is termed '**placement spraying**'. For example, LDP spraying may be undertaken when the area to be treated is close to downwind sensitive areas. Medium to coarse droplets (>250µm) have higher sedimentation velocities and are less affected by vertical air movement and turbulence. LDP is usually undertaken using emulsifiable concentrate (EC), dry flowable (DF) or wettable powder (WP) formulations and water volumes greater than 30 L/ha.

The aircraft has to be swath tested and maintain accurate flight paths over the crop to ensure an even spray coverage and to prevent 'striping'. LDP spraying may reduce drift and is suitable for herbicide spraying.

Considerations for LDP spraying:

- During application, the aircraft should be positioned straight and level above the crop.
- Aircraft boom height should not be greater than 3 m above the top of the cotton canopy.
- Boom length should be 65% of wingspan or less and the boom should be at least 25 cm below the trailing edge of the wing.
- Orientate the nozzles parallel to the airstream (i.e. parallel to the undersurface of the wing).
- Optimum liquid supply pressures are 200 - 400 kPa (30 - 60 psi).
- Use nozzles that generate droplets of >250µm. Micronair AU5000® nozzles are designed for ULV application and are not ideally suited to LDP spraying.



## 7.3 Calibration

*Note: SPRAYpak is a handbook for cotton growers, so calibration of aircraft is not detailed in this section. For more information on the calibration of aircraft, contact the AAAA.*

Spray nozzle wear results in increased output and variable distribution. Calibration improves spray application efficiency by minimising the amount of pesticide required for an operation and by ensuring that the sprayer produces the appropriate droplet spectrum. It is only through accurate calibration that the grower can be sure the correct effective dose of pesticide is being applied.

Sprayers that have been fitted with spray controllers require calibration to check the speed measuring device and the flow meter for accuracy. The operator manuals provide details for specific equipment. To calibrate any sprayer, the following equipment should be available:-

- A calibrated jug or measuring cylinder (1 Litre)
- Tape measure (100 m), calculator, notebook and pencil
- Stopwatch or wrist watch (with a seconds indicator)
- Small brush to clean nozzles (soft bristles)
- Performance and output charts for the nozzles or outlets to be used.

## Preliminary measurements

### A. Nozzle output (L/min)

- Check the pressure drop between the nozzle and the pressure gauge on the controls.
- Clean all the nozzles and filters thoroughly.
- Fill the spray tank with clean water and operate the pump at the specified RPM, and the nozzles at the desired pressure according to the nozzle charts.
- Use a calibrated jug to collect the output from each nozzle for one minute and record the volume.
- Compare this to the manufacturers nozzle performance tables and replace any outlets that vary by more than 10% from specifications.
- Note the number and type of nozzles per row of cotton (it may vary from 1 to 5, depending on stage of season).

**Total spray boom output(L/min) = Sum of all individual nozzle outputs (L/min).**

### B. Operating speed (kph)

- For tractors and groundrigs that are fitted with ground speed sensors, check equipment calibration under field conditions. Refer to the manufacturer's operating manual.
- For tractors and groundrigs that are **not** fitted with ground sensors: Measure out 100m in the field to be sprayed. Select the gear and RPM for comfortable operation and measure the time taken to cover the 100m that has been marked out. Do a couple of runs and average the times.

**Operating speed (kph) = Distance travelled (m) ÷ Time taken (sec) x 3.6.**

*Note: 3.6 is the factor that converts m/sec to kph.*



## C. Effective sprayer width (m)

**Broadcast application:** Nozzle spacing (m) x Number of nozzles.

**Row application:** Row width (m) x Number of rows being sprayed.

**Band application:** Band width (m) x Number of rows being sprayed.

Approximate band widths for different crop heights (1m rows):

Crop height (cm)	Band width (m)
10	0.30
15	0.30
30	0.40
40	0.50
60	0.75
80	0.90
90	0.95
100	1.00

## Spray calculations

### 1. Application volume (L/ha sprayed):

Note: Label directions refer to the volume applied per sprayed area. This formula calculates application volume per **sprayed** hectare.

**Application volume (L/ha sprayed) = Total boom output (L/min) x 600 ÷ Tractor speed (kph) ÷ Effective width (m)**

*Note: 600 is the factor that converts L/min to L/hr and kph x m to Ha/hr.*

### 2. Flow rate for a known application volume (L/min):

**Output (L/min) = Application volume (L/ha sprayed) ÷ 600 x Speed (kph) x Effective width (m).**

### 3. Amount of product to be added to the spray tank:

**Amount (L or Kg) = Spray tank volume (L) ÷ Application volume (L/ha) x Product label rate (L/ha or Kg/ha).**



#### 4. Band / Paddock ratio:

**Band / Paddock ratio = Band width (m) x No. of rows ÷ Sprayer swath width (m)**

Solid planting (1m rows):	Sprayer swath = Number of rows x 1.0 (m)
Single skip planting (1m rows):	Sprayer swath = Number of rows x 1.5 (m)
Double skip planting (1m rows):	Sprayer swath = Number of rows x 2.0 (m)

*If using tramline or irregular row widths, measure the distance from the centre of one spray run to the centre of the next spray run.*

#### 5. Amount of product required for the paddock area:

**Product (L or Kg) = Paddock size (Ha) x Product rate (L/ha or Kg/ha) x Band / Paddock ratio.**

#### 6. Paddock area (Ha) that can be completed with each full spray tank:

**Paddock hectares / tank = Tank size (L) ÷ Application rate (L/ha sprayed) ÷ Band / Paddock ratio.**

#### 7. Sprayer output per paddock hectare:

**Output (L/ha paddock) = Application rate (L/ha sprayed) x Band / paddock ratio.**



Photo: TeeJet Australasia Pty. Ltd.

## 7.4 Nozzles

*Note: There are a number of nozzle and outlet suppliers in Australia. Examples are shown in this section to illustrate the operation of a particular nozzle type, not as an endorsement of that particular brand. Operators should discuss their requirements with a qualified spray equipment supplier.*

All nozzles fitted to agricultural machinery should be fitted with diaphragm check valves ('non-drip' valves) to prevent dripping and stop the pesticide application as soon as the spray control valve is shut off by the operator. These should be maintained at the same time as nozzles are checked. Chemical resistant diaphragms should always be used.

### CP® nozzles

CP® nozzles are hydraulic and produce a fan shaped pattern by forcing the liquid through an orifice and then over the surface of a deflector. Unlike standard nozzles, CP® nozzles have an 'orifice disc' which has a number of differently sized orifices which can be rotated in the nozzle body to control flow rate. Droplet sizes can be altered by changing the angle of the deflector plate. The larger the angle of deflection, the smaller the droplets. A faster airspeed also produces smaller droplets by causing increased air shear.

Fig. 7.11. CP®-03-s nozzle



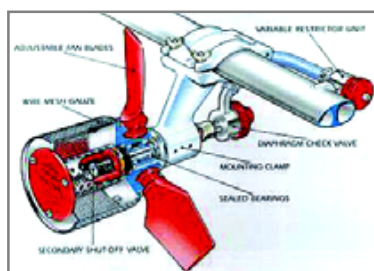
Source: CP Spraying Equipment Inc.

### CE units (Centrifugal energy nozzles)

The Micronair AU5000® has been widely adopted in Australia due to the ability to change the size of the droplets it emits, and the ease with which it handles most agricultural formulations. Droplets generated by the Micronair AU5000® are generally less than 250 µm (VMD), which makes the unit very suited to both low volume (LV) and ultra low volume (ULV) insecticide application. These outlets are commonly referred to as 'micronairs'. These are seldom used on groundrigs.

Droplet size can be altered by altering the blade angles change the cage rotation speed. Faster cage speeds will produce smaller droplets, so each CE unit should be fitted with a transducer so that rotation speed can be monitored during flight. Provided the manufacturer's recommended operating guidelines are followed, CE units will produce a relatively uniform spray droplet spectra.

Fig. 7.12. Micronair AU5000® rotary atomiser.



Source: Micronair AU5000 Operators Handbook



## Cone nozzles

These nozzles produce a cone-shaped pattern of spray droplets, with a size range best suited to the application of insecticides and fungicides. There are ‘hollow’ and ‘solid’ cone nozzles but only the former are recommended because they produce an even range of droplet sizes. Hollow cone nozzles tend to produce smaller sized droplets than fan nozzles at equivalent flow rates.

Hollow cone nozzles release droplets at a slower ‘exit’ velocity, so they may be subjected to environmental conditions (e.g. evaporation) for longer periods before deposition on the target.

The cone nozzle functions as the result of spray liquid being forced through slots in a ‘swirl’ plate into a swirl chamber that leads onto the outlet orifice. The design of the swirl plate slots and depth of the swirl chamber influences the resulting spray

**Figure 7.13. Cone nozzles.**

Hollow cone



Solid cone



Source: Spraying Systems Co.

## Fan nozzles

The patterns produced by these nozzles are fan-shaped, and spray application is like a paintbrush operation. The pesticide is forced into a nozzle chamber then out through a rectangular or lens shaped orifice (hole). Orifice sizes vary considerably.

### a) Even fan nozzles

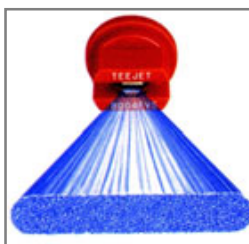
Even fan nozzles have rectangular edged orifices and produce an even pattern of droplets across the full swath covered by the spray. They are suited to band application of herbicides, and banding insecticides when using a single nozzle over the cotton row.

### b) Flat or tapered fan nozzles

These nozzles have an orifice that ends in a point at either end of its width (lens shape). This results in reduced droplet distribution at the two edges of the spray swath.

**Figure 7.14. Flat fan nozzles.**

Even fan



Tapered fan



Source: Spraying Systems Co.



Setting adjoining nozzles with an overlap attains even distribution across the sprayed area. The correct overlap can be achieved by matching the fan angle designed into the nozzle and distance from the spray target.

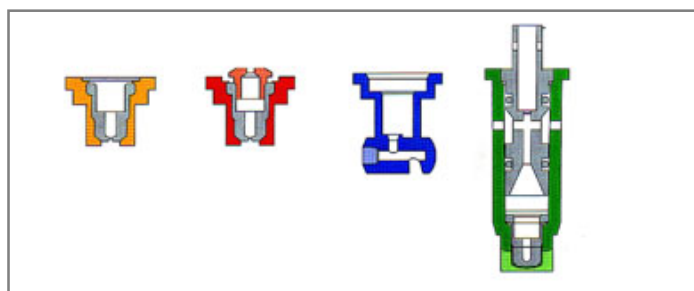
In addition to overlap, the nozzles are offset at an angle 10–15° to the boom so that there is no interference between the spray patterns generated by each nozzle. Most modern nozzle housings are the ‘quick-fit’ type and these automatically angle the nozzles across the boom.

Flat fan nozzles are versatile and can be used in a range of spraying applications in cotton, and produce less ‘fine’ droplets than hollow cone nozzles. They are the most commonly used nozzles because of this versatility and their relatively low cost compared to many other types.

### Drift reduction nozzles

These nozzles produce fewer small droplets that may drift off-target, by manipulating pressure and using innovative designs. Generally the design incorporates a pre-orifice plate that reduces the speed of liquid hitting the nozzle, increases droplet size, and reduces drift.

**Figure 7.15. Drift reduction nozzles** L to R: Extended range, Drift Guard®, Turbo® and Air induction (AI®) nozzles.



Source: Spraying Systems Co.

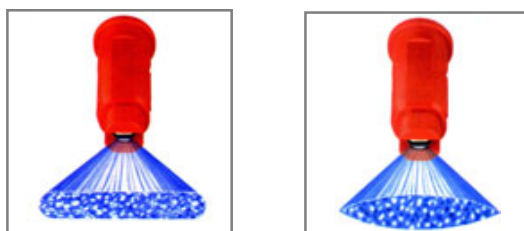
### Twin fluid nozzles

#### a) Passive twin fluid nozzles (e.g. Air induction nozzles)

Venturi type nozzles, such as the air induction (AI) use a pre-orifice to create a high velocity liquid stream, and then draw air into the stream through a side opening. This mixture of air and liquid is then discharged at a low exit velocity which creates very coarse droplets with air inclusions. Generally, these nozzles require pesticide mixtures containing the correct amount of surfactant to allow the air-filled drops to form. Designs vary, but the air is usually sucked into the spray chamber by a venturi on the nozzle body (see above). These nozzles produce large to coarse droplets which reduces drift under suitable conditions.

**Figure 7.16. Air induction nozzles.**

Air induction even fan (left) and air induction tapered fan (right) nozzles.



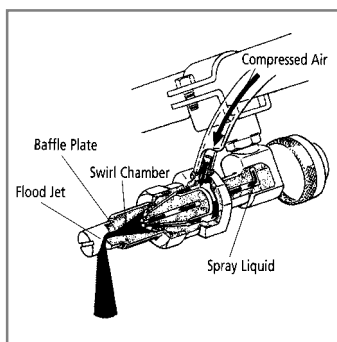
Source: Spraying Systems Co.



### b) Active twin fluid nozzles (e.g. Airtec®)

Twin fluid nozzles have twin independent supply lines providing air and liquid respectively. The nozzles have a first stage chamber where primary atomisation takes place, and the air then forces droplets through an orifice onto the deflector plate of an anvil jet nozzle. The impact on the deflector plate produces secondary atomisation and a flat fan spray pattern.

**Figure 7.17. Airtec® twin fluid nozzle.**

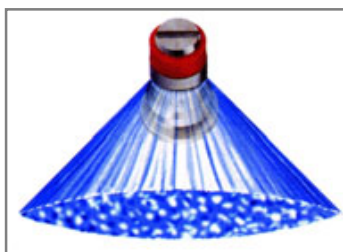


Source: Airtec Australia

### Flood and anvil nozzles

In flood nozzles the spray liquid is forced through an orifice which regulates flow (and provides primary atomisation) then onto a deflector plate that provides secondary atomisation and a fan spray pattern. These nozzles produce large droplets which may reduce drift, and are suited to application of systemic herbicides and some insecticides.

**Fig. 7.18. Flood nozzle.**

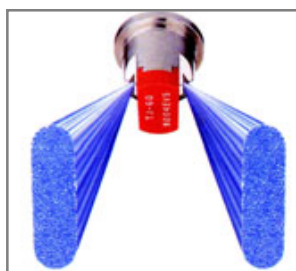


Source: Spraying Systems Co.

### Twin jet nozzles

Twin jet nozzles produce two fan spray patterns from each nozzle. Twin jet nozzles can be used for banding or to improve spray penetration into dense foliage or crop residues. These nozzles produce smaller droplets for improved coverage and are generally used for ground application of insecticides.

**Fig. 7.19. Twin jet nozzle.**



Source: Spraying Systems Co.



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## Twin cap nozzles

Twin cap nozzles have a specially adapted bayonet cap that holds two nozzles. This may give greater control over droplet size, crop penetration and coverage. The nozzle combination may allow additional speed and application volume without compromising quality.

Fig. 7.20. Twincap® nozzle.



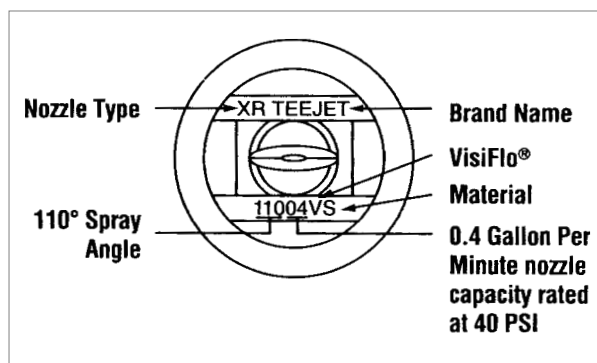
Source: Lurmark



### 7.4.1 Nozzle performance

Information about the performance, type and construction material is printed on most hydraulic nozzles. Personnel who are involved in equipment set-up should be trained to read the information printed on nozzles and in the manufacturer's nozzle charts.

Fig. 7.21. Nozzle information.



Source: Spraying Systems Co.

Figure 7.21 shows typical information that is embossed onto nozzles. In this example the following information is contained in the codes:

- XR            Extended range (XR) type
- Teejet        Made by TeeJet (Spraying Systems Co.)
- 11002VS     110° spray angle @ 40psi pressure (2.75Bar)  
0.2 USgal/min @ 40psi pressure (0.8l/min@2.75Bar)  
Visiflow (V) colour coding  
Stainless steel (S) orifice.

In the past, each manufacturer had their own coding systems, but now nozzle coding and colours are becoming more standardized under new ISO standards.

### Nozzle output

Nozzle output should always be checked pre-season and regularly throughout the season to check output. Nozzles that vary more than 10% from the manufacturers' specifications should be replaced.

All nozzle manufacturers produce nozzle output tables that show the output from a nozzle at different pressures. Many tables also have calculations showing application volume (broadcast application) at different tractor speeds. Table 7.22 shows output volumes for a range of flat fan nozzles operating at different pressures.



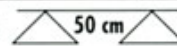
Growers should always check application volumes using the calibration procedures described in Section 7.3.

The nozzle performance should be matched to the required application volumes and droplet sizes required for the pesticide being applied. For example, if greater application volumes are required, select a larger capacity nozzle rather than increasing the working pressure outside the optimal range.

Most nozzle manufacturers also have BCPC droplet size classification tables that are available from suppliers.

Figure 7.22. Nozzle output table (Fan nozzles).



		l/min	l/ha  50 cm												
			4 km/h	5 km/h	6 km/h	7 km/h	8 km/h	10 km/h	12 km/h	16 km/h	18 km/h	20 km/h	25 km/h	30 km/h	35 km/h
<b>DG80015*</b> <b>DG110015</b> (100 mesh)	2.0	0.48	144	115	96.0	82.3	72.0	57.6	48.0	36.0	32.0	28.8	23.0	19.2	16.5
	2.5	0.54	162	130	108	92.6	81.0	64.8	54.0	40.5	36.0	32.4	25.9	21.6	18.5
	3.0	0.59	177	142	118	101	88.5	70.8	59.0	44.3	39.3	35.4	28.3	23.6	20.2
	4.0	0.68	204	163	136	117	102	81.6	68.0	51.0	45.3	40.8	32.6	27.2	23.3
	5.0	0.76	228	182	152	130	114	91.2	76.0	57.0	50.7	45.6	36.5	30.4	26.1
<b>DG8002*</b> <b>DG11002</b> (50 mesh)	2.0	0.65	195	156	130	111	97.5	78.0	65.0	48.8	43.3	39.0	31.2	26.0	22.3
	2.5	0.72	216	173	144	123	108	86.4	72.0	54.0	48.0	43.2	34.6	28.8	24.7
	3.0	0.79	237	190	158	135	119	94.8	79.0	59.3	52.7	47.4	37.9	31.6	27.1
	4.0	0.91	273	218	182	156	137	109	91.0	68.3	60.7	54.6	43.7	36.4	31.2
	5.0	1.02	306	245	204	175	153	122	102	76.5	68.0	61.2	49.0	40.8	35.0
<b>DG8003*</b> <b>DG11003</b> (50 mesh)	2.0	0.96	288	230	192	165	144	115	96.0	72.0	64.0	57.6	46.1	38.4	32.9
	2.5	1.08	324	259	216	185	162	130	108	81.0	72.0	64.8	51.8	43.2	37.0
	3.0	1.18	354	283	236	202	177	142	118	88.5	78.7	70.8	56.6	47.2	40.5
	4.0	1.36	408	326	272	233	204	163	136	102	90.7	81.6	65.3	54.4	46.6
	5.0	1.52	456	365	304	261	228	182	152	114	101	91.2	73.0	60.8	52.1
<b>DG8004*</b> <b>DG11004</b> (50 mesh)	2.0	1.29	387	310	258	221	194	155	129	96.8	86.0	77.4	61.9	51.6	44.2
	2.5	1.44	432	346	288	247	216	173	144	108	96.0	86.4	69.1	57.6	49.4
	3.0	1.58	474	379	316	271	237	190	158	119	105	94.8	75.8	63.2	54.2
	4.0	1.82	546	437	364	312	273	218	182	137	121	109	87.4	72.8	62.4
	5.0	2.04	612	490	408	350	306	245	204	153	136	122	97.9	81.6	69.9
<b>DG8005*</b> <b>DG11005</b> (50 mesh)	2.0	1.61	483	386	322	276	242	193	161	121	107	96.6	77.3	64.4	55.2
	2.5	1.80	540	432	360	309	270	216	180	135	120	108	86.4	72.0	61.7
	3.0	1.97	591	473	394	338	296	236	197	148	131	118	94.6	78.8	67.5
	4.0	2.27	681	545	454	389	341	272	227	170	151	136	109	90.8	77.8
	5.0	2.54	762	610	508	435	381	305	254	191	169	152	122	102	87.1

Source: Spraying Systems Co.

## Height of application

In all cases, height of application should be determined to give the best coverage. This information is included in manufacturers nozzle information booklets.

For aerial applications a general recommendation is that the aircraft wheels should be about 1-2 m above (application boom should be about 3 m) the crop canopy during application. If the aircraft is too low, 'striping' may occur. If the aircraft is too high, the risks of droplet evaporation and drift increase.

Boom height for ground rig applications will be determined by the nozzle type and configuration. Refer to Section 7.3 for considerations when band spraying. For broadcast spraying the nozzle patterns should overlap to give even coverage. Refer to nozzle manufacturers' guidelines for optimum heights for different nozzle types. Where multiple nozzle configurations and/or droppers are used, consult the nozzle supplier for optimal boom heights and nozzle configurations, and check these regularly during field operation.



## Check the spray coverage

Even when correct setup procedures have been followed, the spray coverage should be checked in the field under the prevailing conditions.

- Start the spray boom,
- Check that all nozzles (outlets) are operating properly,
- Stand with the sun behind the spray pattern and view the coverage,
- Check the pattern, overlap and band width (as applicable),
- View the spray as normal field operations continue,
- Check frequently during the job.

**Fig. 7.23. Inspect nozzles using the sun to highlight the spray patterns.**



Photo: Hardi

More detailed coverage studies can be done using sensitive paper and/or dyes in the spray mix and these are summarised in Section 7.6.

## Change worn or faulty nozzles

Nozzles should be changed if they are malfunctioning or if output varies more than 10% from the manufacturers specifications. Nozzle specification and output tables can be obtained from your nozzle supplier. Ensure that proper safety procedures are followed and appropriate personal protective equipment is worn while changing nozzles. Never change nozzles while the boom is operating or pressurised.

## Cleaning nozzles and outlets

Effective filtration is essential to prevent nozzle blockages or impaired performance as a result of partially blocked nozzles. Nozzles should be cleaned with a soft brush (e.g. a used toothbrush) or a jet of compressed air. Do not clean the nozzle by putting it in your mouth to blow through it. Do not use wire or any other hard material to 'poke' into the orifice. It is useful to carry a small 'nozzle' kit including a soft brush, spare nozzles, caps and filters, a supply of clean water and soap and an old towel.

CE cages and other application equipment should be cleaned using soapy water and a soft brush. All equipment should be rinsed in cold water and dried thoroughly.

## 7.5 Droplets

The cotton grower faces a difficult problem. How can a small quantity of a biologically active chemical be distributed evenly to control a pest species?

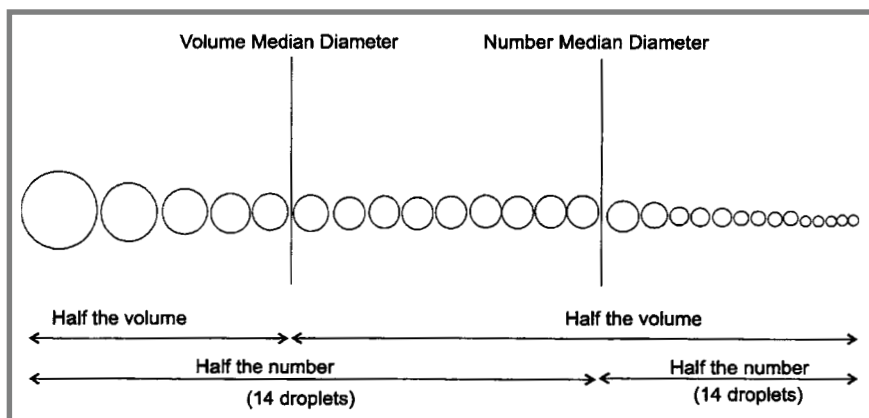
Traditionally the problem has been overcome by formulating a pesticide as a liquid, thus enabling the applicator to transport the material to the crop and apply the solution to the target site as a spray.

### 7.5.1 Droplet size

Unfortunately, no spray nozzle produces droplets which are all the same size, and all nozzles generate a range of droplet sizes. Droplets that are 10 $\mu$ m and even 100 $\mu$ m in diameter may not be visible to the naked eye. As an example, the full stop at the end of this sentence is approximately 600 $\mu$ m in diameter. It would be considered a coarse droplet in spray application technology.

Volume Median Diameter (VMD) is the most commonly used descriptor of droplet size. The VMD divides the droplet spectrum into two equal parts. One half of the total volume is made up of droplets larger than the VMD, and the other half made up of droplets that are smaller than the VMD. Two different nozzles may produce the same VMD but may actually produce quite different droplet spectrum. Similarly, the Number Mean Diameter (NMD) divides the droplet sample in half by number of droplets as shown in Figure 7.24.

Figure 7.24 Diagrammatic representation of VMD and NMD.



Source: C-PAS

VMD may not be an easy measure for many operators to understand, so the British Crop Protection Council (BCPC) and the manufacturers have developed a droplet size classification table. Droplet size classifications are now based on these British Crop Protection Council (BCPC) specifications, and in accordance with ASAE Standard S-572. The droplet size classifications for a nozzle are determined by comparing it to six standard reference nozzle types. Nozzles are tested at different pressures and the droplet cloud produced is classified as very fine, fine, medium, coarse, very coarse or extremely coarse.



The droplet size classifications are:

<u>Code</u>	<u>Classification</u>	<u>Droplet size (VMD)</u>
VF	Very fine	<135µm
F	Fine	135 - 245µm
M	Medium	245 - 330µm
C	Coarse	330 - 475µm
VC	Very coarse	475 - 540µm
XC	Extremely coarse	>540 µm

These classifications are published in manufacturers' nozzle catalogues which are available from spray equipment suppliers. The droplet size classifications are a guide to assist growers in selecting nozzles that are suitable for a particular spray job.

### 7.5.2 BCPC (ASAE S-572) Spray Quality Classifications

Nozzle manufacturers provide information on the spray quality produced by their nozzles at various pressures according to the British Crop Protection Council (BCPC) and American Society of Agricultural Engineers (ASAE S-572) standards.

*Note: It is possible for one type of nozzle to produce a range of spray qualities depending on the operating pressure. The higher the pressure, the smaller the droplets will be, hence the finer the spray quality that is assigned in the nozzle performance charts.*

Figures 7.26 and 7.27 show the difference in droplet size classifications between standard flat fan nozzles (XR) and drift guard (DG) flat fan nozzles, at various pressures. Although the nozzles produce similar spray patterns, the DG type produces larger droplets at the same operating pressure, which may assist in reducing drift. Effectiveness on the target pest must be considered if droplet sizes are significantly larger as there may be some reduction in coverage, and the fan pattern may not be as wide. When using hydraulic fan nozzles for insecticide application, they should be operated at the highest pressure to produce the desired droplet spectrum.

#### What are the BCPC (ASAE S-572) classifications?

The BCPC classifications represent spray quality (the range of droplet sizes produced by a nozzle). This spray quality is determined by comparing a nozzle's output (droplet spectrum) at a given pressure against a set of standard reference nozzles. This is done using a laser based instrument, which means that the spray quality given to a particular nozzle when it has been compared to the reference nozzles will be the same classification regardless of where, when or how it was measured.

There are three (3) key measurements in determining the spray quality classification, the DV(0.1), DV(0.5) = VMD and the DV(0.9) which are taken from the cumulative volume fraction.

- DV(0.1)** 10 % of the spray volume exists in droplets smaller than this size (by diameter).
- DV(0.5)** 50 % of the spray volume exists in droplets smaller (VMD) than this size (by diameter) in microns. 50% of the spray volume is in droplets larger than this size.
- DV(0.9)** 90 % of the spray volume exists in droplets smaller than this size.

These three measurements are plotted on a graph to produce boundaries for each spray quality classification. An example of a reference curve from a Malvern laser instrument used for this purpose is shown in Figure 7.27.



Fig. 7.25. Droplet size classifications -  
Flat fan nozzles.


### XR TeeJet® (XR)

	bar						
	1	1.5	2	2.5	3	3.5	4
XR8001	M	F	F	F	F	F	F
XR80015	M	M	M	F	F	F	F
XR8002	M	M	M	M	M	F	F
XR8003	M	M	M	M	M	M	M
XR8004	C	C	C	M	M	M	M
XR8005	C	C	C	C	C	M	M
XR8006	C	C	C	C	C	C	C
XR8008	VC	C	C	C	C	C	C
XR11001	F	F	F	VF	VF	VF	VF
XR110015	F	F	F	F	F	VF	VF
XR11002	M	F	F	F	F	F	F
XR11003	M	M	M	F	F	F	F
XR11004	M	M	M	M	F	F	F
XR11005	M	M	M	M	M	M	F
XR11006	C	M	M	M	M	M	M
XR11008	C	C	M	M	M	M	M

Source: Spraying Systems Co.

Fig. 7.26. Droplet size classifications -  
Drift Guard™ fan nozzles.

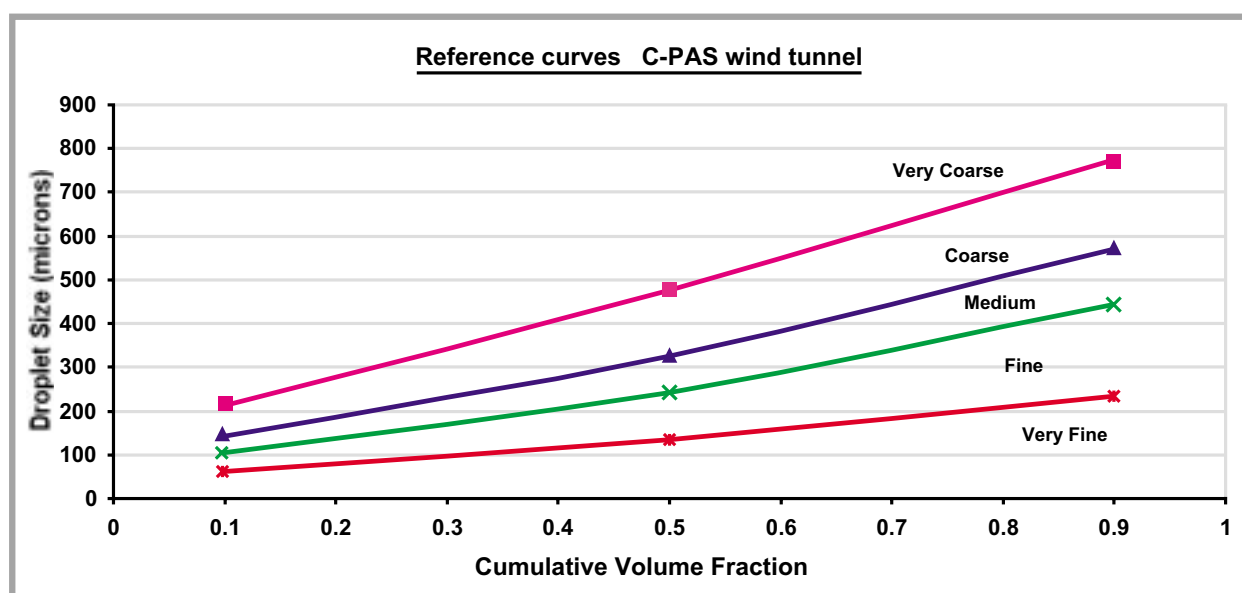
### DG TeeJet® (DG)

	bar				
	2	2.5	3	3.5	4
DG80015	M	M	M	F	F
DG8002	C	M	M	M	M
DG8003	C	C	M	M	M
DG8004	C	C	C	C	M
DG8005	C	C	C	C	C
DG110015	M	F	F	F	F
DG11002	M	M	M	M	M
DG11003	C	M	M	M	M
DG11004	C	C	M	M	M
DG11005	C	C	C	M	M

Source: Spraying Systems Co.



Figure 7.27. Example of BCPC reference curves used to determine spray quality.



Source: C-PAS.

Cumulative volume fraction is the proportion of the spray volume that exists in droplets smaller than a particular size (microns). For example 0.1 is the DV(0.1), 0.5 is the DV(0.5) also known as the VMD and 0.9 is the DV(0.9).

### How the reference curves are used to determine BCPC classifications.

Figure 7.27 (above) shows the outputs of a set of reference nozzles. Each line on the chart is the output of a single reference nozzle, and the lines are the boundaries between different spray classifications.

When commercially produced nozzles are tested against the reference nozzles, output is compared to the reference curves. If any one (or more) of the three (3) critical measures, the DV(0.1), DV(0.5) or DV(0.9) determined for the test nozzle is less than those of a reference nozzle it is assigned the finest spray quality classification that the DV(0.1), DV(0.5) or DV(0.9) falls within.

### Using the Reference Curves to Understand Nozzle Outputs.

Understanding the reference curves will assist operators to better understand the manufacturers nozzle spray quality classifications.

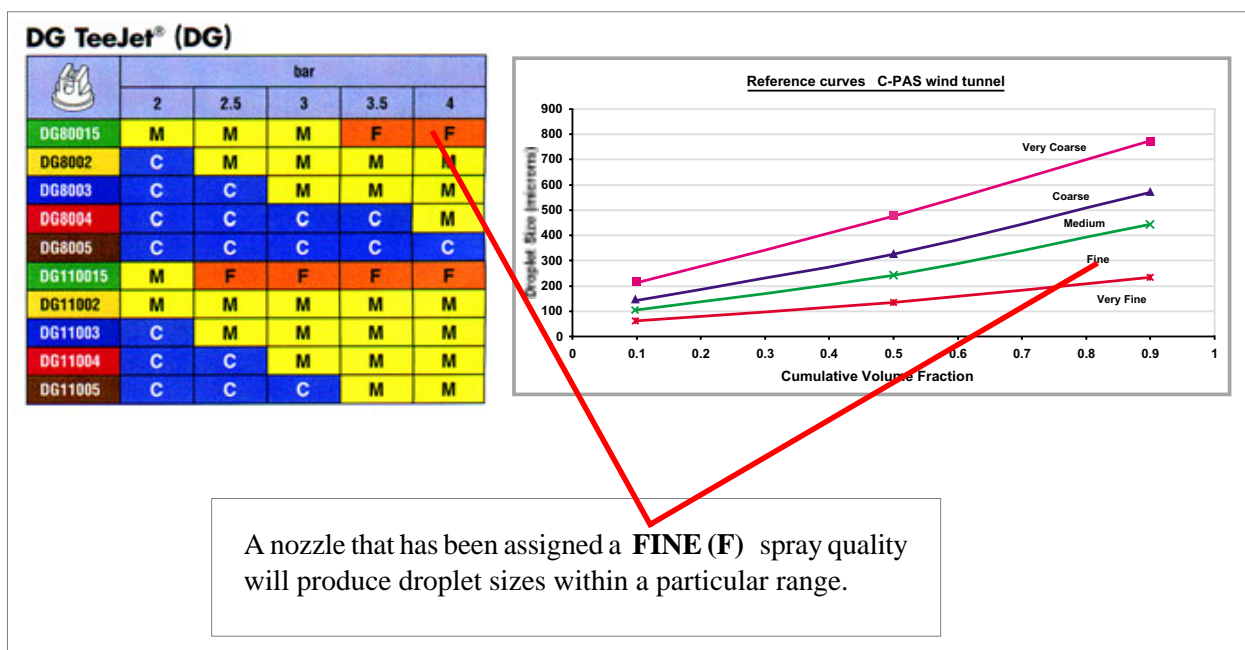
Figure 7.28 shows that a nozzle classified as FINE will have a DV(0.1) between 60 microns and 100 microns. This means that that 10 % of the spray volume is smaller than these sizes. A fine nozzle will also have a DV(0.5) or VMD between 130 microns and 240 microns.

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 240 microns). In the example above, 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 130 microns.

When due consideration of how droplets of various sizes behave in differing conditions, and the reference charts is undertaken, the kinds of droplet sizes that can be expected when operating those can be estimated. This is an important part of planning for pesticide applications.



Figure 7.28. How the reference curves are used for nozzle droplet classification tables.



Spray equipment can be adjusted to produce droplets within a desired range suited to varying targets. Table 7.30 shows some characteristics of very fine, fine-medium and coarse droplets and indicates most common uses for each of the size groups.

The influence of size on droplet physical behaviour can significantly affect the efficacy of a pesticide. Some examples are summarised in Table 7.29.

### Canopy penetration

Coverage throughout the canopy and underneath leaves is best achieved by small droplets. Large droplets move downwards due to gravity and will generally be deposited on horizontal surfaces and the uppermost parts of the plant canopy. If the crop has an open canopy, larger droplets will penetrate into the foliage without the assistance of turbulence.

### Evaporation risk

Small droplets of water based pesticides will evaporate more rapidly under hot dry conditions leading to a rapid reduction in the diameter of the initial droplet and possible movement off target.

### Drift potential

Small droplets pose the highest risk of spray drift. Generally, under normal spray conditions, large droplets will only be moved sideways by the prevailing wind.

### Coverage

As droplet size decreases, more droplets are produced from the same volume of spray. Large droplets require a spray volume increase to maintain comparative coverage.

### Gravity effects

As a droplet diameter increases towards the desirable range for herbicides ( $>200 \mu\text{m}$ ), it becomes increasingly subject to gravitational influence. As droplet size increases, the effects of any local wind turbulence lessen and deposition on flat and horizontal surfaces is likely. The opposite is true for small droplets.



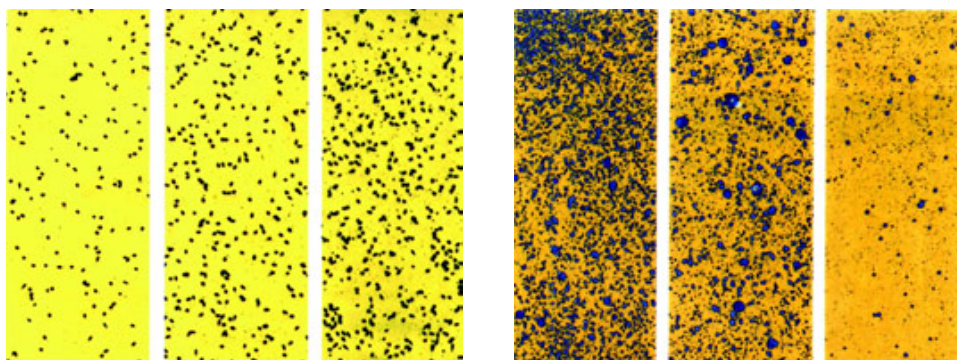
Table 7.29. Influence of size on droplet behaviour.

	Droplet size groups (BCPC)		
	V. fine	Fine - Med.	Course+
Size	<150 µm	150 - 350 µm	>350 µm
Canopy penetration	High	Medium	Low
Evaporation risk	High	Medium	Low
Drift potential	High	Medium	Low
Coverage / volume	High	Medium	Low
Inertia / gravity effect	Low	Medium	High
Uses	Insecticides. Fungicides.	Insecticides. Contact herbicides.	Insecticides. Soil applied pesticides.

Source: QDPI.

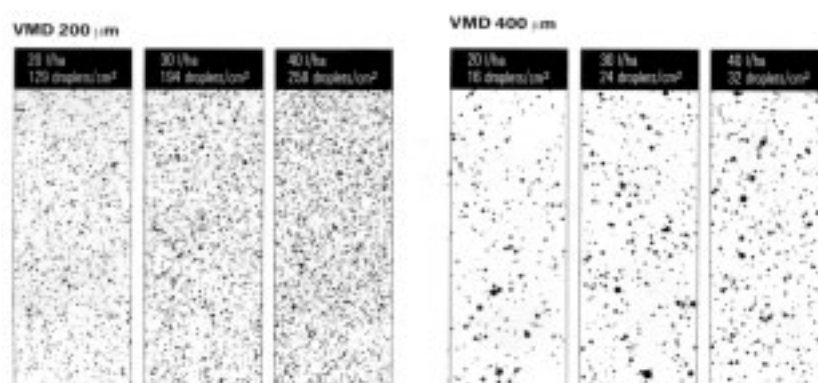
Figure 7.30 shows water sensitive dye after exposure to water droplets. Figure 7.31 compares deposits on water sensitive paper at three application rates (20, 30, 40 l/ha) for two droplet sizes (VMD 200µm and 400µm). The difference in coverage between the two droplet sizes (at all three application rates) is clear.

Figure 7.30. Actual water sensitive paper samples showing droplets produced from a spinning disc sprayer (left) and a hydraulic nozzle (right).



Source: Novartis.

Fig. 7.31. Comparison of droplet sizes and distribution on sensitive paper.



Source: Novartis.



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### 7.5.3 Droplet application

Spray application involves three main phases:

- |                             |  |
|-----------------------------|--|
| <b>Droplet generation</b>   | - creating a large number of droplets from a body of liquid. |
| <b>Droplet transmission</b> | - movement of the droplets from the nozzle to the target.    |
| <b>Droplet capture</b>      | - droplets depositing on the target.                         |

Droplets are generated in three main ways:

- |                           |   |
|---------------------------|---|
| <b>Hydraulic pressure</b> | The spray liquid is forced under pressure through a small specially designed orifice. The most common types of hydraulic nozzles used for cotton spraying are hollow cone and flat fan nozzles. CP® nozzles are also hydraulic (See Section 7.3).   |
| <b>Centrifugal force</b>  | <p>By subjecting the liquid to centrifugal energy, and by metering liquid onto a spinning disc, droplets are generated at the edge of the disc as liquid is spun off into space. Droplet size is influenced by the rotational speed of the disc, the nozzle design and liquid flow rate. Spinning cages as used in “Micronair®” units are an extension of this principle.</p> <p>These are normally referred to as centrifugal energy nozzles (CE) and they generally produce a narrower range of droplet sizes than hydraulic nozzles.</p> |
| <b>Air shear</b>          | Metering liquid into a high velocity jet of air generates droplets as the liquid is torn into small particles by the impact of the moving airstreams. Systems employing this principle are normally referred to as air shear nozzles. The same principle applies to aerial applications when airspeed and angle of the nozzle are manipulated to produce air shear of the liquid into droplets.   |

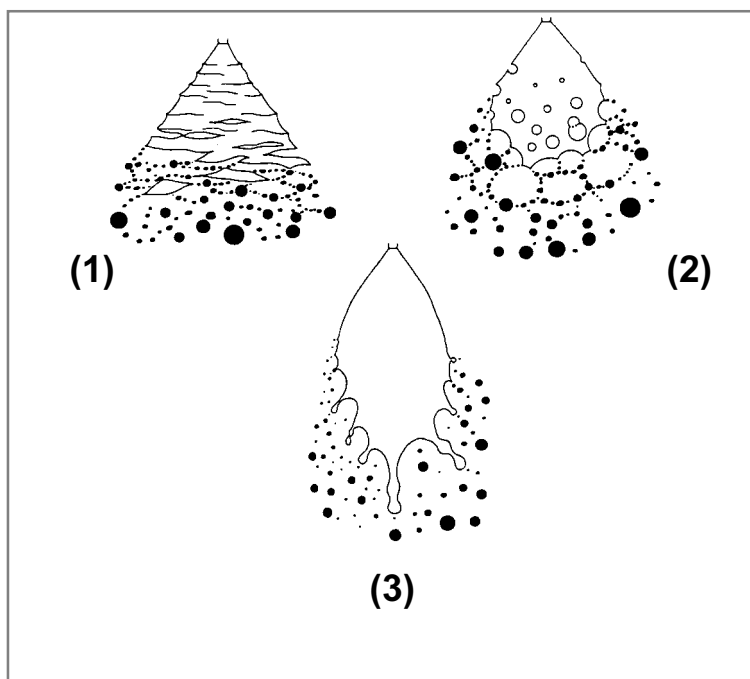
As forces (described above) are applied to a spray solution, they change the physical shape of the liquid. Whether liquids are water or oil based, they do not compress easily so they tend to change shape when subjected to a force. Generally, there are several phases of droplet formation:

- |                           |  |
|---------------------------|--|
| <b>Sheet formation</b>    | Sheets of liquid appear immediately through a hydraulic nozzle or sometimes just beyond the edge of a spinning disc.   |
| <b>Ligament formation</b> | The formation of ligaments or “strings” of liquid and sometimes liquid cylinders at the edge of sheets.  |
| <b>Droplet formation</b>  | The final stage is when the ligaments or sheets of pesticide disintegrate into droplets. The sheets and ligaments disintegrate either at the edge of a sheet (Rim disintegration), it’s centre (Perforation) or through a wave motion breaking up the liquid body. These modes of disintegration are shown in Figure 7.32. |



**Figure 7.32. Hydraulic nozzle - droplet formation.**

(1) Wavy sheet disintegration, (2) Perforated sheet disintegration, (3) Rim disintegration.

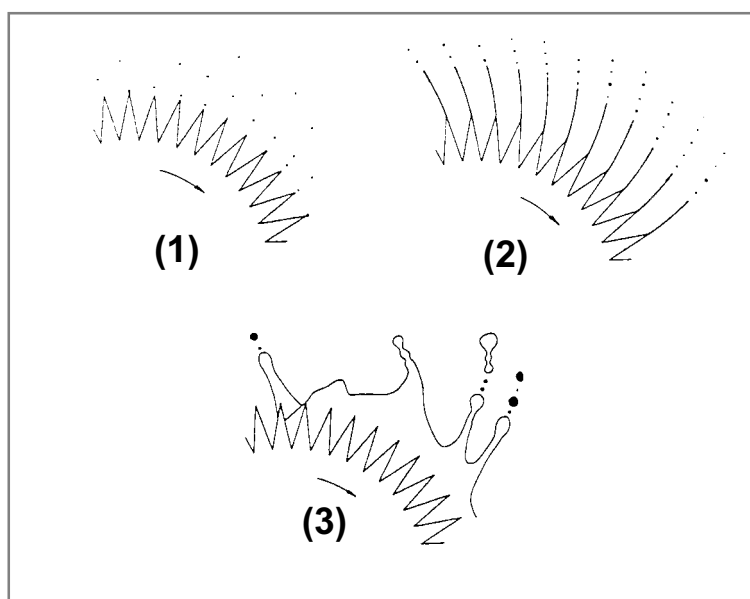


Source: QDPI.

Centrifugal energy nozzles may produce droplets directly from the edge of the spinning disc (Figure 7.33). This typically occurs at low flow rates, and as flow rate increases, ligaments form which then break into droplets. At very high flow rates, flooding of the spinning disc may occur producing a sheet of liquid which disintegrates into droplets in the same mode of disintegration as hydraulic nozzles.

**Figure 7.33. Centrifugal energy nozzle.**

(1) CDA - Normal operation, (2) CDA - Ligament formation, (3) Sheet formation - breakdown of CDA.



Source: QDPI.

Liquid properties also influence droplet generation. Increasing the viscosity (thicker liquids) will result in larger droplets being produced or incomplete droplet formation.

## 7.5.4 Droplet transmission

Once the droplet is generated it must be transferred to the target for the pesticide to be effective. The movement of a droplet through the air is influenced by the sprayer type, droplet size, the droplet's initial speed of travel, gravity and prevailing weather conditions.

Gravity causes droplets to fall towards the earth's surface. This is referred to as **sedimentation**. The speed reached by a falling droplet when there is a balance between air resistance to its fall and the pull of gravity, is known as its terminal or sedimentation velocity. Sedimentation velocity varies with the diameter of the droplet, being low for small droplets and significantly higher for large droplets.

**Table 7.34. Estimated survival times of water droplets under differing relative humidity conditions.**

Droplet diameter (µm)	T (°C) <i>Difference between wet and dry bulb temperatures</i>			
	6	8	10	12
	Droplet survival times (seconds)			
10	0.2	0.2	0.1	0.1
20	0.8	0.6	0.5	0.4
50	5.2	3.9	3	3
100	21	16	13	10
200	83	63	50	42
500	333	250	200	167
Droplet diameter (µm)	T (°C) <i>Difference between wet and dry bulb temperatures</i>			
	6	8	10	12
	Distance fallen before a droplet disappears (cm)			
10	0.03	0.02	0.02	0.02
20	0.5	0.4	0.3	0.3
50	20	15	12	10
100	313	234	188	156
200	5,000	3,750	3,000	3,500
500	80,000	60,000	48,000	40,000

Source: QDPI.



The longer a droplet takes to fall to earth, the more time it is exposed to drift and evaporation. Low humidity and high temperatures can cause droplets, particularly water-based droplets, to reduce in diameter by evaporation, and remain exposed to possible sideways movement for even longer time periods.

The main weather conditions that influence droplet transmission are

- Temperature
- Relative humidity
- Local wind speed and direction.

Table 7.34 shows estimated survival times for water droplets under a range of conditions. Under most spraying conditions in Australian cotton, smaller water based droplets ( $<100\mu\text{m}$ ) are less likely to survive long enough to reach the target.

Temperature and relative humidity influence the evaporation of the droplets, and local wind conditions affect the direction of movement of the droplets. Even after the water component of a droplet has evaporated, the active ingredient and/or oil components may remain intact and may be carried long distances. The importance of meteorological factors in relation to droplet behaviour and spray management is discussed in Section 3.

Initial energy imparted by a nozzle and the use of high speed air streams can also influence the transmission of droplets. However, once this force is removed, droplets (particularly small droplets) fall entirely under the influence of gravity and wind.

### 7.5.5 Droplet capture

For pesticide spraying to be effective, droplets must be deposited on the target. Target size, shape and orientation, droplet velocity and diameter and weather conditions all influence droplet deposition on the target.

Large droplets will deposit on horizontal surfaces such as the ground or broadleaf weeds due to sedimentation. Deposition on vertical surfaces or the lower surface of a leaf is increased by using smaller droplets which are subject to horizontal wind movement and turbulence.

If the movement of small droplets is considered in a horizontal wind flow, objects such as branches and leaves on crops cause air to be accelerated and deflected around them. Small droplets in the air will also be deflected around the objects unless they have sufficient mass and energy to leave the accelerating air and impact on the target surface. Figure 7.35 shows schematic diagrams of the flow of air around flat (e.g. leaf) and cylindrical objects (e.g. branch).

The ratio of the number of droplets striking the object to the number which would strike if the air was not deflected is called the catch efficiency. The greater the catch efficiency, the greater the deposition on the target. In general the catch efficiency increases as:

- Diameter or width of the target decreases.
- Droplet velocity between the nozzle and the target increases.
- Droplet size increases.

Consequently, if small droplets are applied over a crop, the catching efficiency of the canopy would increase if wind speeds were elevated (greater) and the crop consisted of numerous small branches and hairy surfaces.

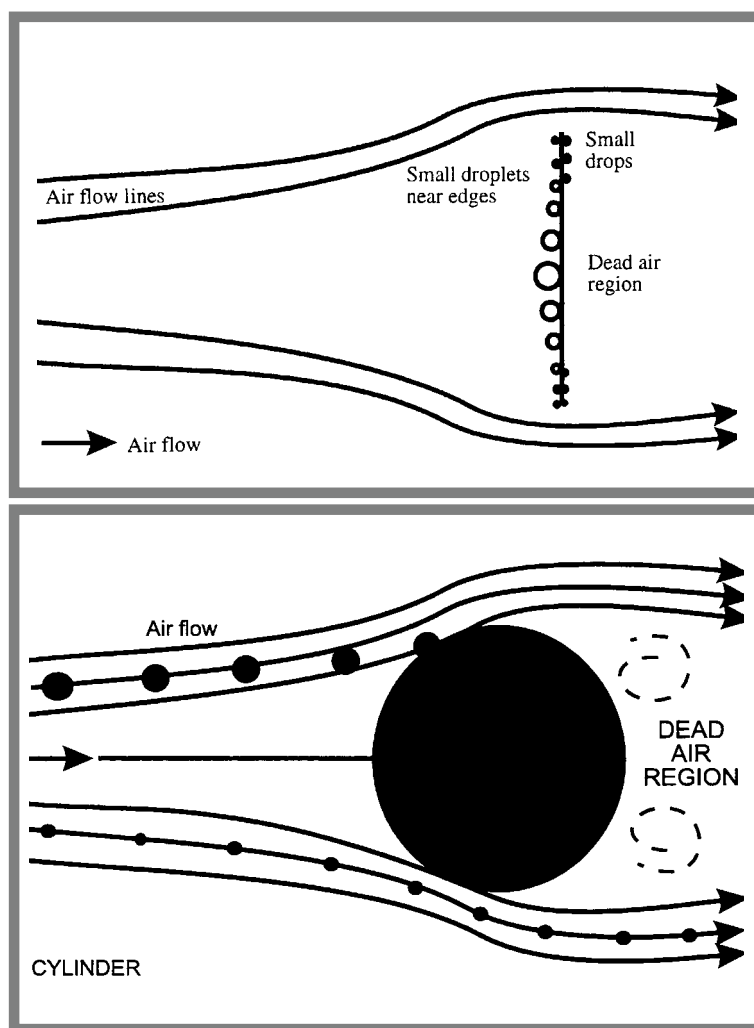


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**The use of elevated winds to increase catch efficiency can also increase the drift potential of a spray. Caution is required.**

Most natural surfaces are not smooth. Plant leaves may have a complex rough surface comprising small protruding spikes, hairs and/or veins. All these factors help to increase the catch efficiency of the plant. Movement of the leaves due to airflow also increases the catch efficiency.

**Fig. 7.35. Air flow around a flat plate and a cylinder.**



Source: C-PAS

Not all droplets that reach a target will be retained on the target. Droplets which strike the target tend to flatten on the surface. If insufficient kinetic energy or momentum is lost on contact with the leaf surface, the droplet can contract and bounce away. Small droplets may have insufficient kinetic energy and roll off the target surface. Large droplets can have excess kinetic energy and shatter on impact. Droplet retention is therefore a function of droplet kinetic energy, pesticide formulation, surface tension, droplet size and leaf morphology. The waxy surface coating on many leaves may reduce the catching efficiency of aqueous sprays.

Adjuvants that reduce surface tension aim to decrease surface tension so that the droplet 'flattens' (without rolling off the leaf), increasing pesticide contact with the leaf. The grower should note that where a surfactant (wetting agent) is recommended to reduce surface tension and increase retention, the addition of too much agent (or an incorrect product) can decrease the surface tension excessively and cause droplets to run off leaf surfaces.



### 7.6.3 Advanced analytical techniques

Droplet sizing can be performed by a variety of fully automated, semi-automated or manual methods.

- Laser droplet sizing instrumentation enables droplet size to be estimated while the droplets are airborne. There are three main methods of laser analysis, being (a) Laser Diffraction (b) Laser Shadowing and (c) Laser Doppler Anemometry (LDA).
- Manual methods can be used to determine droplet size when the spray cloud has reached the target and is deposited either on an artificial surface or a natural surface such as leaves.
- A number of in-flight methods can be used to measure droplet spectra. These include photographic methods, holographic techniques, light attenuation, light scattering, laser doppler droplet sizing and optical array spectrometers.
- Other methods of droplet measurement require the capture of droplets on or in a suitable medium so that droplets are made visible for sizing. To make the droplets more visible a fluorescent dye is added to the spray mixture and the spray deposition is examined under UV lights.

A number of specialists in advanced spray application research (e.g. C-PAS) can perform controlled investigations using specialised equipment. C-PAS uses Malvern 2600 laser diffraction equipment which allows different spray equipment to be tested under comparable and repeatable conditions. These results can then tested in the field under operating conditions.

#### Useful contacts:

Water and oil sensitive papers:      TeeJet Australasia Pty. Ltd.  
PO Box 7138  
GEELONG WEST      3218  
Victoria  
  
Tel: (03) 5223 3020      Fax: (03) 5223 3015  
eMail: teejeto@spray.com

Flourescent yellow dye      G. Furness  
SARDI Research Centre  
PO Box 411  
LOXTON      5333  
  
Tel: (08) 959 100      Fax: (08) 959 199

Ultra violet (blacklight blue) flourescent light bulbs:  
Lawrence and Hanson Electrical Distributors Pty. Ltd.  
Branches in most cities in Australia.



## 7.6 Analysing spray applications in the field

### 7.6.1 Water and oil sensitive paper

Water sensitive paper (WSP) has a yellow surface on one side which is specially coated so that when water based droplets contact this surface it is stained dark blue. Oil sensitive paper, in contrast, stains black when in contact with certain oil based formulations. Deposits on such cards can be used to determine the coverage as droplet deposition (droplets/sq.cm) or percent area cover. Water sensitive paper is not recommended for accurate drop sizing due to the variability of spread factor as a result of initial drop size and relative humidity. Droplets less than 100 µm do not stain the card if the relative humidity is less than 50%. Under very humid conditions or in a recently watered crop, the paper may turn blue as it absorbs moisture from the surrounding air.

The best way to use these cards is to cut them into strips and staple the strips to the cotton canopy at differing levels. Estimates of droplet recovery can be made (and replicated) by determining the average droplet numbers deposited per unit area on the cards over a significant sampling area.

Refer to “Groundrig Spray Application in Cotton and Grain Industries” published by ChemCert Australia Incorporated; J.H. Kent (Editor).

As a rough guide droplet numbers on the upper canopy should ideally exceed 40 droplets per sq. cm for most pesticide applications. Where accurate determination of droplet numbers and the percentage area covered is required, cards can be sent to specialists (e.g. C-PAS) for computer based image analysis.

Water and oil sensitive paper can be purchased in Australia from all TeeJet Australasia Pty. Ltd. distributors.

### 7.6.2 Flourescent markers

The spray application equipment is set-up and checked in the field that is to be tested. Flourescent dyes are mixed with clean water in the spray tank. The spray is then applied, and perhaps a few variations of nozzles and set-up configurations are tested.

Once the dye has dried, some of the cotton leaves are picked and taken to a dark room and examined under a UV light. If the trials are being carried out at night, the leaves can be examined in the field using portable UV lights. Examination of the sprayed leaves under UV light will cause the dye to ‘flouresce’ brightly so the droplet sizes and coverage can be examined.

*Care: Direct viewing of UV light can be harmful to eyes. Shields should be fitted to the lights, eye protection should be worn and exposure should be kept to a minimum.*

*Flourescent dyes may persist on the crop and affect marketing. Check this before using the dyes.*

This technique is a practical method of estimating coverage, but if accurate droplet size or deposition figures are required, then advanced analytical techniques will be required.



## 7.7 Pumps, pressure gauges and ancillary equipment

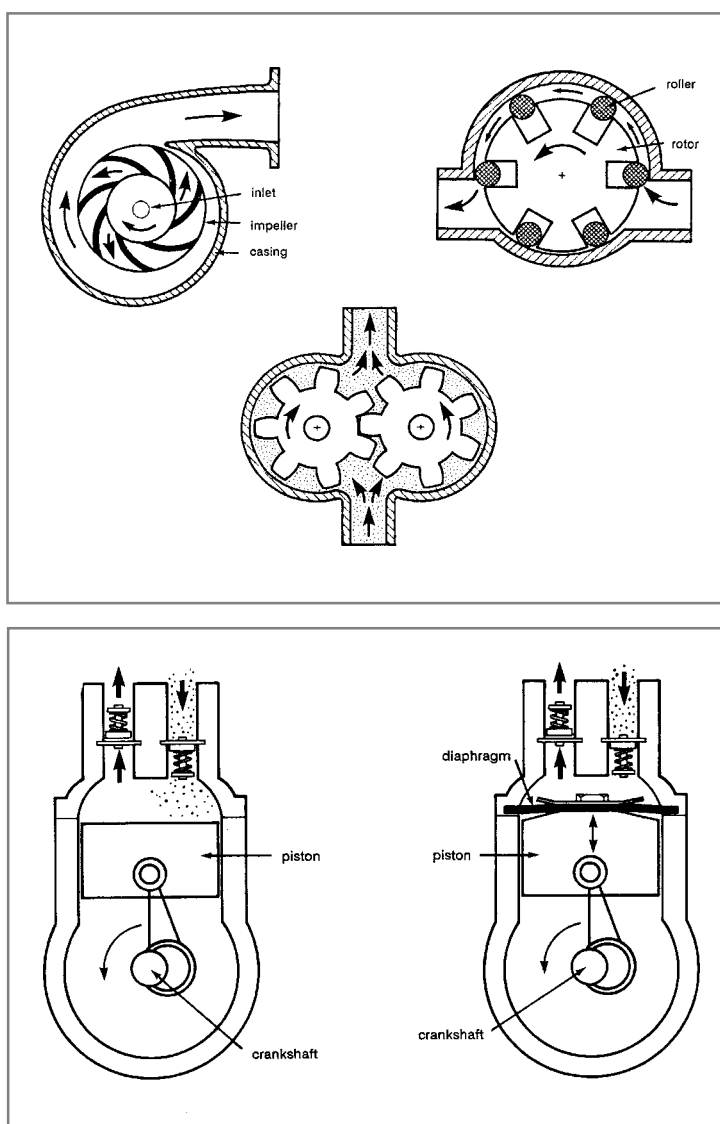
### Pumps

There are several types of pumps for spray equipment (Fig. 7.36) and selection depends on:

- Maximum flow rate required
- Required pressure at the nozzles (or outlets)
- Characteristics of the pesticides being used.

**Figure 7.36. Typical pump types used for pesticide application.**

*Top left: Centrifugal pump, Top right: Roller pump, Centre: Gear pump, Bottom left: Piston pump, Bottom right: Diaphragm pump.*



Source: QDPI.

Table 7.37 shows why centrifugal pumps are the most commonly used type of pump in spray application equipment, due to their high durability and relative cost effectiveness.



Table 7.37. Comparison of different pumps.

Pump type	Max. pressure (bar)	Max. pressure (psi)	Relative durability	Relative cost
Piston	30	435	low	high
Diaphragm	30	435	high	high
Centrifugal	7	100	high	medium
Roller vane	15	220	low	low
Gear	15	220	low	low

Source: QDPI.

## Required pump capacity

Pump capacity is calculated to meet the boom requirements when it is operating at full capacity at the correct pressure.

$$\text{Pump flow rate required} = \text{Number of nozzles} \times \text{Flow rate per nozzle (L/min)}^* \times 1.15^{**}$$

\*Flow rate per nozzle value should be based on the largest nozzles to be used on the spray boom.

\*\* As a rule of thumb, allow 15% extra capacity over maximum requirement to ensure that there is sufficient bypass for tank agitation.

## Pressure gauges

A pressure gauge should:

- Have a scale that is suitable for the range of applications that the equipment is likely to be used for. A range of 200 kPa to 700 kPa (2.0 - 7.0 bar) (15 - 50 psi) is usually adequate.
- Be easy to read from the operators seat.
- Be damped with glycerine to cut out vibration (or be an electronic type that is isolated by electrical wires).

It is recommended that hydraulic spray units carry at least two pressure gauges positioned to measure any pressure drop between the main gauge and the furthest outlet point. Ease of visibility from the driving position enables these to be used to spot problems caused by filter or other blockages. Pressure gauges should not be mounted inside the cab unless they are isolated from the pesticide (e.g. diaphragm or electronic types).

## Pressure regulators

Where a positive displacement pump is used, a bypass pressure regulator must be used. A bypass regulator has an adjustable spring loaded valve which opens to bypass spray mix back to the tank, once the working pressure has been reached. It is essential that the valve has the capacity to bypass the whole pump flow to the tank when the nozzles are turned off (e.g. when turning at the edge of a field).

The pressure regulators should be checked frequently, and be monitored during spraying via the pressure gauges.



## **Agitators**

Proper agitation of the spray mix is important for all pesticides. Agitation can be done in several ways (or a combination) depending on the pesticide and formulation being used:

Bypass agitation is sufficient for most pesticides used in cotton. The bypass agitation line should be in the bottom of the tank to minimize foaming.

Jet or 'venturi' agitation should be used for low concentrations of wettable powder and suspension concentrates. The agitator should be fitted to a separate high pressure line from the tank to ensure that the agitator pressures are maintained.

Mechanical agitation consisting of paddles or propellers on a rotating shaft may be necessary for large tanks and/or high concentrations of wettable powder pesticides.

## **Filters**

A good filter system that is regularly cleaned will ensure fewer stoppages due to blocked nozzles. Fan and some low drift nozzles are particularly sensitive to blockages. Filters can be fitted in line where they should have enough capacity to operate properly for at least 3-4 hours, and carry a finer mesh (e.g. 100 -120 mesh) than the nozzle filters that may be fitted. Effective filters ensure more efficient spray operations and reduced wear and tear (caused by abrasion) in the spray system.

### **Tank inlet filters**

The tank inlet filter is located under the lid for top filling and in line where a closed system is used. Inlet filters are the first filters in the system and are to prevent any larger objects or potential blockages entering the tank. Inlet filters are usually 50 mesh and should be cleaned daily or if contamination occurs (e.g. a dirty load of water).

### **Suction filters**

Suction filters are fitted to the pump intake line in the bottom of the spray tank to filter the pesticide mixture before it enters the pump. These filters are generally constructed of brass to prevent collapsing due to the suction created by the pump. Piston pumps require better intake filtration than diaphragm pumps.

### **Line filters**

Line filters are incorporated into the main spray lines which supply pesticide to the nozzles. They filter out solid contaminants before the mixture reaches the nozzles. Line filters are usually a finer mesh rating than the nozzle filters and should be cleaned daily.

### **Nozzle filters**

Refer to the manufacturers recommendations for suitable filters to match the nozzles that you are using. Check and clean frequently, especially if the formulation is not a liquid.

## **Check valves**

Non-drip nozzle assemblies are readily available and are recommended for use on all spray booms. It is difficult to decontaminate the rubber diaphragms incorporated into the units after exposure to some herbicides such as 2,4-D and other 'phenoxy' herbicides. Under these circumstances, replace all diaphragms before spraying cotton, and request chemical resistant (e.g. neoprene) replacement parts.



Because it is extremely difficult to completely decontaminate a sprayer after it has been used to spray phenoxy herbicides, it is common practice on cotton farms not to use phenoxy herbicides at all, or to have a completely separate sprayer to apply phenoxy and other herbicides.

### **Boom section shut-off valves**

It is common for spray units to have three operational spray lengths—either side arm and a centre section—which can be operated together or individually. Control of the spray supply to each section is manually applied using a lever stopcock or electronically by a switch activating a solenoid.

### **Droppers**

Droppers are an ‘extension’ inserted between the nozzle body and the tip. Droppers are used to ensure good coverage of the lower leaves of the cotton crop. Thick walled nylon or polythene tubing is often used because it is cheap, lightweight, easy to assemble and does not corrode. However, nylon is flexible and this may result in inaccurate pesticide placement in the crop. Spring loaded steel or copper droppers which can only swing backwards (if they strike an obstacle) will provide more accurate application.

Droppers may have multiple nozzles to improve coverage, and the nozzle holders should be strong enough to withstand constant contact with the cotton branches. Avoid configurations which are likely to ‘strip’ squares or bolls from the branches during operation.

### **Shielded sprayers**

Groundrig sprayers may be fitted with spray ‘hoods’ or shields that cover the application area during spraying. The shields may also protect the spray from wind, and reduce upward movement if the shields are properly designed and fully enclose the nozzles. Partial shields may be used to protect the crop from herbicides whilst spraying inter-row weeds. There are many designs of sprayer shields for inter-row spraying, row / band spraying and overall spraying, and details can be obtained from all major spray equipment suppliers.

**Figure 7.38** Spray shields fitted to apply pesticide to individual rows.



Photo: Custom Ag. Products Inc.



## In-field positioning and guidance systems

### Markers

In dryland areas and prior to 'hilling-up' in irrigated cotton, a marking system is essential if 'overlapping' and/or 'stripping' are to be minimised. They are also helpful for maintenance spraying during the fallow period. The type of marker needed depends on the boom spray design and environmental requirements. The following types of markers are available:

#### Foam markers

Foam (blob dobber) markers are widely used by both growers and contractors. The white colour is suitable for in-crop and bare-fallow spray operations, but visibility problems may be encountered in crop stubble. For efficient operation of foam markers, use clean water and follow the manufacturer's recommendations closely. Foam life varies from less than 30 minutes to three hours, depending on quantity, bubble size, humidity and temperature.

#### Paint markers

Water-based paint has been used as a replacement for the traditional silver streak (diesel based) in spray markers. It costs less and a range of colours can be used depending on the conditions; a sky blue colour has shown promise for winter cereal stubble and in stressed or dead sorghum.

#### Disc markers

Disc markers mounted on the boom are very effective. They give a positive mark in both a fallow and young crop situation but have limitations in dry soil conditions, and where cotton rows have been carefully prepared. Make sure the disc throws soil away from the swath being sprayed.

### Electronic guidance systems

In furrow irrigated crops the row hills provide accurate guidance for most ground rig operations, but global positioning systems (GPS) guidance systems may be necessary in conditions where it is difficult for the operator to count rows or in dryland situations where there are no rows for guidance. For aerial application and for more accurate guidance for groundrigs, GPS provides the most accurate method of in-field guidance.

#### GPS and DGPS

Global Positioning System (GPS) and Differential Global Positioning System (DGPS) tracking. This system uses a constellation of 24 satellites in orbit approximately 20km above the earth. When the system was originally made available for civilian use, the US military introduced an intentional error 'called 'selective availability' (SA) to prevent use by hostile forces to pinpoint US targets. To overcome this error, earth stations were set up at known locations to provide signals, and these were compared to the satellite signals to provide a range correction and improve positional accuracy. This technique is known as differential GPS. Selective availability has now ceased and GPS guidance using satellite signals alone provide sufficient accuracy for most spraying operations.



GPS is now used extensively in application equipment for applying pesticides to cotton. The advantages are accuracy, constant monitoring of the job, and reduced reliance on human or visual markers.

GPS is now standard for aerial application in cotton to avoid exposure of human markers, and to provide accurate flight paths.

GPS is not essential in ground rig application, as the operator can calculate spray lanes using the cotton rows. However, it is still preferred so that a record of the application can be stored electronically and the ground rig can be used on flat (i.e. no furrows) country.

Many GPS systems have the added advantage of on-board memory that allows the application path patterns to be examined and printed after the job has been completed.

**Figure 7.39 In-cab GPS guidance and electronic spray management system.**



Photo: Hardi



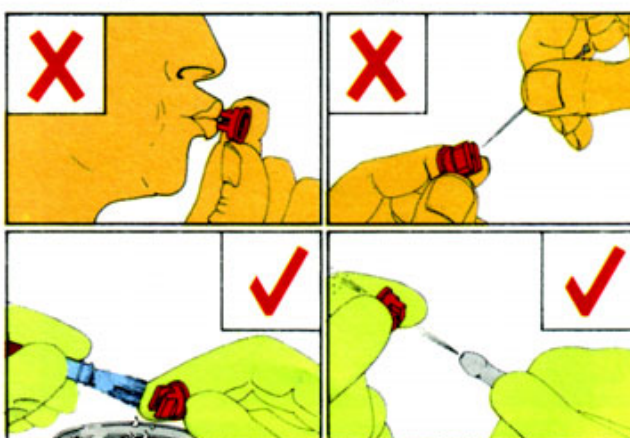
## 7.8 Cleaning and decontamination of equipment

No spraying operation is completed until the equipment used has been properly cleaned out and decontaminated from pesticide residues. Failure to clean the equipment may result in the risk of future contamination and possible crop damage, as well as accelerated equipment deterioration. Growers should check applicator and contractor records and equipment to ensure that reasonable decontamination procedures are being followed. This becomes particularly important in IPM programs to ensure that soft option pesticides or attractants are not contaminated by other chemicals.

The spraying system should be thoroughly flushed and decontaminated at the end of each day and whenever the pesticide mixture is changed.

Nozzles should be cleaned with a soft brush (e.g. a used toothbrush) or a jet of compressed air. Do not clean the nozzle by putting it in your mouth to blow through it. Do not use wire or any other hard material to 'poke' into the orifice.

Fig. 7.40. .Correct techniques for cleaning nozzles.



Source: Lurmark

Spray application equipment should also be cleaned thoroughly before moving to other fields to prevent the spread of weeds and diseases such as *Fusarium spp.*

The vehicle or aircraft should be cleaned both internally and externally. All cab filters should be checked and maintained, and the cab should be left open to 'air' before the vehicle is stored.

Oily residues may be slippery and endanger personnel who are loading or working on the machinery.

During operation, aircraft and groundrigs are very visible and clean machinery projects a public image of professional attention to detail.

Always check the pesticide label for any specific cleaning and decontamination procedures.

**Table 7.41. Cleaning procedures for various pesticides.**

Chemical group	Cleaning agent(s) per 100 L water	Instructions
General cleaning Atrazine, Simazine.	250g powdered detergent	Flush sprayer with fresh water. Drain and capture washing water. Flush cleaning mixture through the sprayer and leave overnight. Flush next day with two washings of clean water.
Organophosphates eg. Predator®  Carbamates eg. Lannate®	125g powdered detergent + 1 Litre household ammonia	Thoroughly agitate. Flush a small amount through the sprayer and leave overnight. Flush next day with at least two washings of clean water.
Organochlorides eg. Thiodan®	500g washing soda + 125g powdered detergent	Rinse inside of tank and flush a small amount through the system. Fill and let stand for 2 hours. Flush twice with clean water.
Glyphosate (e.g. Roundup®)	Clean water	Rinse thoroughly several times with clean water.
Broadstrike®, Lontrel® Verdict® Fusilade®	500ml liquid washing detergent (e.g. OMO®)	Flush the system, then quarter fill the tank with water and add the detergent. Start pump and recirculate for at least 15 mins. Drain and flush with fresh water.
Hormone type herbicides a) Water soluble formulations eg. 2,4-D amine, MCPA  b) Oil soluble formulations eg. 2,4-D ester	500g washing soda     4 L kerosene + 500g washing soda + 125g powdered detergent	Half fill spray tank. Start agitation and add washing soda and fill. Flush a small amount through the system. Let stand for a minimum of 2 hours. Drain then flush system with two lots of clean water.
Sulfonylureas eg. Ally	350mls household chlorine bleach (35g/l available chlorine) <b>Never mix bleach and ammonia.</b>	Flush with cold water. Half fill spray tank. Start agitation and add bleach and fill. Flush a small amount through the system. Let stand for a minimum of 2 hours. Drain then flush system with two lots of clean water. Nozzles and filters should be cleaned separately.
After cleaning and decontamination the main system, remember to check all filters, screens and nozzles. Maintain any faulty parts after decontamination is completed.		



## Appendix 1. Useful unit conversions

To convert 	<i>Multiply by</i>	 To obtain
To obtain 	<i>Divide by</i>	 To convert
Acre	0.4047	Hectare
Centimetres	10	Millimetres
Centimetres	0.01	Metres
Cubic feet	0.02832	Cubic metres
Cubic inches	16.387	Cubic centimetres
Cubic metres	1,000	Litres
Gallon (US)	4.405	Litres
Gallons (UK)	3.785	Litres
Grams	1000	Milligrams
Grams	0.001	Kilograms
Hectares	2.471	Acres
Horsepower	0.7457	Kilowatts
Inches	2.54	Centimetres
Kilograms	2.205	Pounds
Kilograms	1000	Grams
Kilograms/sq.cm.	0.9807	Bars
Kilograms/sq.cm.	14.22	Pounds/sq.in.
Kilometres	0.6214	Miles
Kilometres / hr	0.5396	Knots
Kilowatts	1.341	Horsepower
Litres	0.21997	Gallons (UK)
Litres	0.26417	Gallons (US)
Metres	39.37	Inches
Metres/sec	3.6	Kilometres / hr
Miles / hr	0.8684	Knots
Fahrenheit (° F)	$(^{\circ}\text{F} - 32) \div 1.8$	Celsius (° C)
Celsius (° C)	$(^{\circ}\text{C} \times 1.8) + 32$	Fahrenheit (° F)



## Appendix 2. Information sources.

### Contacts

#### Cotton Research and Development Corporation

2 Lloyd Street	Telephone: 02 6792 4088
NARRABRI 2390	Fax: 02 6792 4400
NSW	Website: <a href="http://www.crdc.org.au">www.crdc.org.au</a>

#### Cotton Australia

Level 2, 490 Crown Street	Telephone: 02 9360 8500
SURRY HILLS 2010	Fax: 02 9360 8555
NSW	Website: <a href="http://www.cottonaustralia.com.au">www.cottonaustralia.com.au</a>

#### Cotton Australia. - Regional Offices

St George	Qld	Tel: (07) 4625 4038	Fax: (07) 4625 4053
Dalby	Qld	Tel: (07) 4669 6288	Fax: (07) 4669 6299
Emerald	Qld	Tel: (07) 4982 0611	Fax: (07) 4982 0511
Goondiwindi	Qld	Tel: (07) 4671 5965	Fax: (07) 4671 5978
Narrabri	NSW	Tel: (02) 6792 6041	Fax: (02) 6792 6042
Warren	NSW	Tel: (02) 6847 3688	Fax: (02) 6847 3755
Moree	NSW	Tel: (02) 6751 1852	Fax: (02) 6751 1854
Gunnedah	NSW	Tel: (02) 6742 1800	Fax: (02) 6742 1900

#### Cotton CRC

PO Box 59	Telephone: (02) 6799 1500
NARRABRI NSW 2390	Fax: (02) 6793 1186
	Website: <a href="http://www.cotton.crc.org.au">www.cotton.crc.org.au</a>

#### National Cotton Extension Coordinator

Toowoomba	Qld	Tel: (07) 4688 1398	Fax: (07) 4688 1199
		Mob: 0428 195 485	

#### Senior Development Extension Officer - Pesticide Application

Toowoomba	Qld	Tel: (07) 4688 1564	Fax: (07) 4688 1199
		Mob: 0417 723 259	



**Cotton CRC - Industry Development Officers and District Agronomists**

<b>District</b>	<b>Town</b>	<b>Telephone</b>	<b>Fax</b>	<b>Mobile</b>
Darling Downs	Dalby	(07) 4669 0815	(07) 4669 4966	0427 035 793
Central Qld	Emerald	(07) 4983 7411	(07) 4983 7459	0409 499 691
Macintyre	Goondiwindi	(07) 4671 6711	(07) 4671 2782	0428 879 900
Balonne	St. George	(07) 4625 3299	(07) 4625 3892	0408 710 969
Darling/Lachlan	Griffith	(02) 6960 1353	(02) 6963 0255	0427 107 057
Upper Namoi	Gunnedah	(02) 6742 9279	(02) 6742 2940	0427 007 422
Gwydir	Moree	(02) 6752 5111	(02) 6752 4859	
Macquarie	Warren	(02) 6847 4507	(02) 6847 3664	0408 447 483
Lower Namoi	Narrabri	(02) 6799 1500	(02) 6799 1582	
	Walgett	(02) 6828 1288	(02) 6828 2274	

**Aerial Agricultural Association of Australia (AAAA)**

The Executive Officer  
AAAA  
PO Box 647  
DICKSON 2390  
ACT

Telephone: 02 6262 8256  
Fax: 02 6262 8257

**Centre for Pesticide Application and Safety (C-PAS)**

The Director  
The University of Queensland,  
Gatton 4343  
QLD.

Telephone: 07 5460 1293  
Fax: 07 5460 1283  
Email: [nicholas.woods@mailbox.uq.edu.au](mailto:nicholas.woods@mailbox.uq.edu.au)

**ChemCert Australia Inc.**

The Executive Manager  
Chem Cert Australia Inc.  
PO Box E10  
KINGSTON 2604  
ACT.

Telephone: 02 6933 2177  
Fax: 02 6933 2924

**Cotton Consultants Australia Inc. (CCA)**

The Executive Officer  
CCA  
PO Box 508  
NARRABRI 2390

Telephone: 02 6792 5459  
Fax: 02 6792 5461  
eMail: [ccaao@northnet.com.au](mailto:ccaao@northnet.com.au)



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## Groundrig Operators Association Inc. (GOA)

The Executive Officer	Telephone: 02 6752 9167
Groundrig Operators Association Inc.	Fax: 02 6752 9070
PO Box 845	
MOREE 2400	
NSW	

## Emergency Services

Fire, Ambulance, Police	Telephone: 000
Poisons Information Centre	Telephone: 131 126 (All areas, 24 hours)
Pesticide manufacturers	Refer to the product label or MSDS.

## Websites

### National

<b>Cotton Research and Development Corporation</b>	<a href="http://www.crdc.com.au">www.crdc.com.au</a>
<b>Australian Cotton Cooperative Research Centre</b>	<a href="http://www.cotton.crc.org.au">www.cotton.crc.org.au</a>
<b>Bureau of Meteorology</b>	<a href="http://www.bom.gov.au">www.bom.gov.au</a>
<b>Department of Transport</b>	<a href="http://www.dot.gov.au">www.dot.gov.au</a>
<b>National Registration Authority</b>	<a href="http://www.nra.gov.au">www.nra.gov.au</a>
<b>Standards Australia</b>	<a href="http://www.standards.com.au">www.standards.com.au</a>

### New South Wales

<b>Department of Agriculture</b>	<a href="http://www.agric.nsw.gov.au">www.agric.nsw.gov.au</a>
<b>Department of Land &amp; Water Conservation</b>	<a href="http://www.dlwc.nsw.gov.au">www.dlwc.nsw.gov.au</a>
<b>Environment Protection Authority</b>	<a href="http://www.epa.nsw.gov.au">www.epa.nsw.gov.au</a>
<b>WorkCover</b>	<a href="http://www.workcover.nsw.gov.au">www.workcover.nsw.gov.au</a>

### Queensland

<b>Department of Primary Industries</b>	<a href="http://www.dpi.qld.gov.au">www.dpi.qld.gov.au</a>
<b>Department of Natural Resources and Mines</b>	<a href="http://www.nrm.qld.gov.au">www.nrm.qld.gov.au</a>
<b>Department of Emergency Services</b>	<a href="http://www.emergency.qld.gov.au">www.emergency.qld.gov.au</a>
<b>Department of Employment Training and Industrial Relations</b>	<a href="http://www.detir.qld.gov.au">www.detir.qld.gov.au</a>
<b>Environmental Protection Agency</b>	<a href="http://www.epa.qld.gov.au">www.epa.qld.gov.au</a>



## Further reading.

- Agsafe (1996). **Accreditation Training Manual (7th edition)**. Published by Agsafe Limited, NSW.
- Agsafe (1998). **Farm Chemicals Manual, A guide to safe use and handling**. Published by Agsafe Limited, NSW.
- Agsafe (1998). **Chemical Handling, Storage and Transport, Training Manual**. Published by Agsafe Limited, NSW.
- Aerial Agricultural Association of Australia (1997). **Operation Spray Safe - Pilots' and Operators Manual**.
- Australian Cotton Cooperative Research Centre (2000). **Insect Management in Cotton Pocket Guide**.
- Australian Cotton Cooperative Research Centre (2001). **NUTRIpak - A Practical Guide to Cotton Nutrition**. Ian Rochester (Editor).
- Australian Cotton Industry (2000). **Best Management Practices Manual (2nd edition)**.
- Boyce Chartered Accountants (2000). **Cotton Comparative Analysis - 2000 Crop**. Moree.
- Broadley, R. et. al. (1993). **Pesticide Application Manual (2nd edition)**. Queensland Department of Primary Industries Information Series Q189003.
- Ciba-Geigy. **Correct and Safe Aerial Application of Pesticides**. Application Support Group, Plant Protection, Ciba-Geigy Ltd., Basle, Switzerland.
- Cooperative Research Centre for Sustainable Cotton Production. **ENTOpak - A Compendium of Information on Insects in Cotton**. (Collected papers).
- Cotton Research and Development Corporation (2000) **Insect Resistance Management Strategy**.
- Cotton Research and Development Corporation (2000). **Spray Application Guide - Groundrig Operators**.
- Harden, J. and Whitehead, J.(1995). **Pesticide Application and Safety - Workshop Manual (2nd edition)**. Published by The University of Queensland Gatton College.
- New South Wales Environmental Protection Authority (1988) **Environmental Guidelines - Aerial Spraying Facilities**.
- Pyke, B.A. and Brown, E. H. (1996) **The Cotton Pest and Beneficial Guide**. Published jointly by the Cotton Research and Development Corporation and the Cooperative Research Centre for Tropical Pest Management (Qld).
- Queensland Department of Training and Industrial Relations (2000). **Code of Practice for the Storage and Use of Chemicals at Rural Workplace**.
- Queensland Farmers Federation. **The Environmental Code of Practice for Agriculture**.
- Rural Industries Research and Development Corporation (1999). **Growing Trees on Cotton Farms**.
- Shaw, A.J. and Watson, C.R., (2001). **Cotton Pest Management Guide 2001/2002**.



Standards Australia (1998). **The storage and handling of agricultural and veterinary chemicals.** Australian Standard 2507-1998.

Standards Australia (1997). **The storage and handling of toxic substances.** Australian Standard 4452-1997.

Standards Australia (1998). **The storage and handling of mixed classes of dangerous goods in packages and intermediate bulk containers.** Australian Standard 3833-1998.

Whitehead, J. and Pyke, B. (Eds) (1994). **SPRAYpak - The Cotton Growers Spray Application Handbook.** Published by The University of Queensland Gatton College.

Whitehead, J. and Coleman, E. (1999). **Farm Chemical Storage Guide.** Information Series Q199064. Published by Queensland Department of Primary Industries.

## Legislation

Amendments to specific legislation should also be consulted.

Refer to your BMP manual for brief explanations of the following legislative documents:

### Commonwealth

Road Transport Reform (Dangerous Goods) Regulations (C'wealth) 1997

### New South Wales

Contaminated Land Management Act (NSW) 1997

Dangerous Goods Act (NSW) 1975

Dangerous Goods (General) Regulation (NSW) 1999

Occupational Health and Safety Act (NSW) 1983

Occupational Health and Safety (Hazardous Substances) Regulation (NSW) 1996

Pesticides Act (NSW) 1999

Protection of the Environment Operations Act (NSW) 1997

Road and Rail Transport (Dangerous Goods) Act (NSW) 1997

Waste Minimisation and Management Act (NSW) 1995

### Queensland

Chemical Usage (Agricultural and Veterinary) Control Act (Qld) 1988.

Environmental Protection Act (Qld) 1994.

Health Regulation (Qld) 1996.

Health (Drugs and Poisons) Regulation (Qld) 1996.

Workplace Health and Safety Act (Qld) 1995.

Workplace Health and Safety Regulation (Qld) 1997.

Workplace Health and Safety (Miscellaneous) Regulation (Qld) 1995.

## Codes of Practice

Commonwealth      Australian Dangerous Goods Code.

New South Wales      Code of Practice for the Safe Use and Storage of Chemicals in Agriculture.

Queensland      The Storage and Use of Chemicals at Rural Workplaces - Industry Code of Practice.



## Appendix 3. Risk Management

All applicators and farmers have a common law responsibility (or Duty of Care) to minimise risks associated with the transport, storage, handling, mixing and application of pesticides.

**Hazard**            *A potential source of harm, injury or difficulty.*

**Risk**              *Exposure to the chance (probability) of injury or loss.*

Transporting, storing, mixing and applying pesticides all create hazards to human health and the environment. The level of risk associated with these activities depends on the probability that an activity will cause harm and the seriousness (consequences) of that harm.

Damages caused as a result of pesticide use are considered foreseeable and preventable, and **not** unexpected or accidental.

Adverse environmental impacts or harm to human health caused by pesticide use can have legal and/or financial implications for the parties involved.

***Reducing risk makes good sense.***

### Risk management

A process of identifying hazards, assessing the risk and managing that risk.

#### Step 1: Identify hazards

*Identify the hazards which may be encountered on your cotton farm during pesticide application.*

Start by classifying the pesticide hazards into groups such as:

<b>Transport</b>	- from supplier, - on-farm.
<b>Storage</b>	- on-farm, - depots.
<b>Handling</b>	- movement (lifting etc).
<b>Mixing</b>	- on-farm, - at depots or mobile support units, - disposal of waste, - spills.
<b>Application</b>	- equipment, - pesticide characteristics (eg. toxicity), - off target residues, - clean up.

Once a PAMP has been completed on the broader categories of hazards, and the associated risks are being managed, more detailed categorisation of each pesticide application activity can be undertaken.



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## Step 2: Assess risk

*Assessing risk means measuring it.*

The risk associated with a particular hazardous activity may be **high, medium or low**, depending on the probability of harm occurring, and the consequences of that harm should it occur.

Ask the following questions when assessing risk:

- **Law** Is the activity controlled by legislation?
- **Methods** Have controls been put in place to reduce risk? (Due diligence)
- **Training** Are the personnel involved in the activity adequately trained?
- **Location** Are there sensitive areas nearby?
- **Timing** Is the application being done at an appropriate time to reduce risk?
- **Harm** What harm could the activity cause, and how likely is it to occur?
- **Consequences** How serious are the consequences if harm occurs?

## Step 3: Control risk

*Controlling (or managing) risk means reducing it.*

Action plans provide a means of listing priorities for action. High level risks should be given priority.

- **Identify** Identify the target pest, disease or weed(s) correctly.
- **Select** Select the most effective and least toxic option.
- **Assess** Conduct a risk assessment.
- **Control** Implement risk controls.
  - a. Eliminate the risk by using another method.
  - b. Replace the hazard with a less significant one.
  - c. Isolate hazardous activities from other activities.
  - d. Use engineering/mechanical devices to minimise risk.
  - e. Ensure safe work practices and train operators.
  - f. Use well maintained protective equipment.
- **Record** Maintain accurate records.
- **Team** Involve all personnel in the process of risk reduction.
- **Monitor** Monitor progress and repeat risk assessments when work practices change.



## Appendix 4. Pesticide fate processes

When a pesticide is mixed and applied it is immediately subjected to numerous environmental forces that affect its fate. Generally, these can be grouped into physical and biochemical influences.

Physical or 'transfer' influences

These may include the following:

- (a) **Volatilisation:** If the active constituent or parts of the formulation have a high vapour pressure, these will tend to vaporise after deposition and move away from the target area with ambient air movement.
- (b) **Wind:** Wind can have a significant effect on the fate of pesticides. Many small droplets may be transferred from the target area by wind.
- (c) **Run-off and erosion:** Significant rainfall events shortly after spraying can lead to residue wash off-target, and pesticide movement along with water flow. Similarly any earth that has been sprayed that is moved through erosion will carry residues with it. The amount will be dependent many factors including slope and ground cover.
- (d) **Leaching:** The significance of downward movement of chemical through the soil profile towards the water table varies with the nature of the chemical and the soil type. Sandy soils and highly water soluble compounds not subject to soil adsorption represent the worst scenario (e.g. phenoxy herbicides).

At the other end of the scale some pesticides with very low solubility like Trifluralin through sheer persistence may survive long enough without breakdown to contaminate groundwater. Most pesticides do not pose a threat.

- (e) **Groundwater movement:** If the ground water is contaminated it may be part of a system that supplies water elsewhere.
- (f) **Crop absorption and harvest:** Under some circumstances chemical residues may be moved out of the paddock of use along with the harvested crop.

### Degradation influences

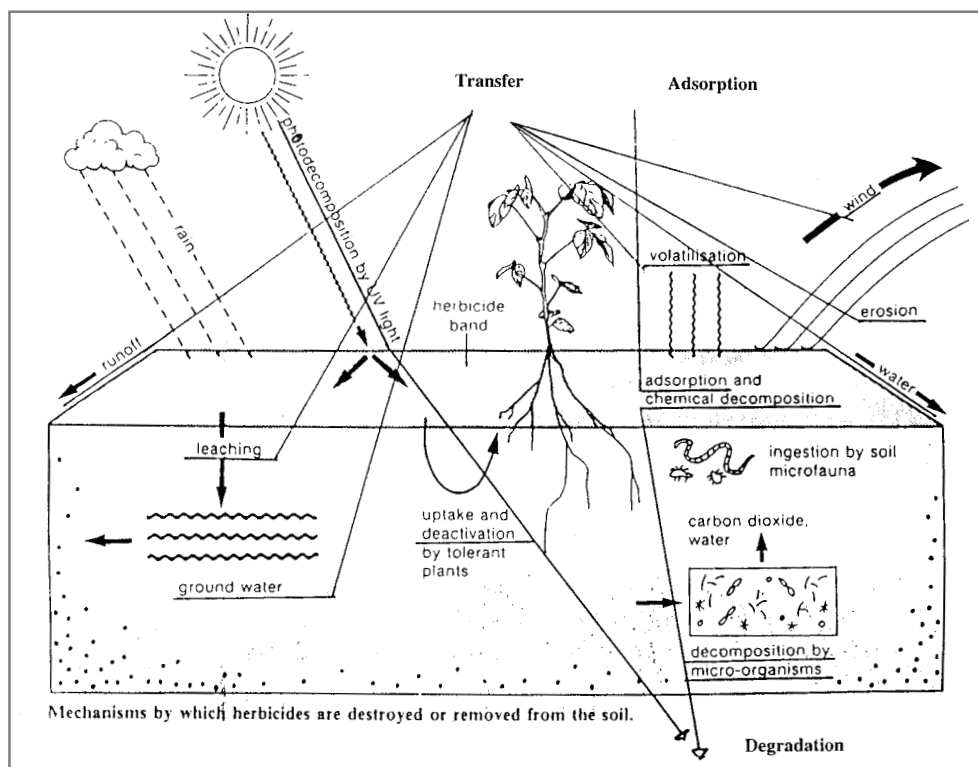
These breakdown systems result in the actual molecule being modified and possibly totally destroyed with its components (eg. carbon, nitrogen, phosphorus, sulphur, oxygen and hydrogen) being reabsorbed into other compounds such as water, carbon dioxide or chloride salts.

These reactions are caused in two ways:

- (a) **Chemical:** There are two major influences. The first is ultra-violet radiation as the residue sits on the target exposed to sunlight. Pesticides vary quite a lot in their sensitivity to UV. The other chemical change is brought about by acid or alkaline soil conditions. Pesticides that are adsorbed to clay can be destabilised by a change in pH. Usually the pH triggers the process known as hydrolysis (decomposition by reaction with water).
- (b) **Bio-degradation:** The great majority of pesticides can be utilised by some soil micro-flora or fauna as an energy source. They attack the molecule and accumulate the energy released by its break-up. The crop itself may absorb the chemical and then assimilate it or de-activate it through enzyme activity.



## Pesticide degradation influences.



## Appendix 5. Bureau of meteorology meteograms

The Bureau of Meteorology has worked with growers in cotton areas to provide services that will provide more reliable weather indications.

Meteograms provide weather outlooks for any location in Australia up to 7 days ahead. They are available by subscription and provide a very cost effective way to look at the future weather for your area. This subscription service is available via the Bureau's 'SILO web site at <http://www.bom.gov.au/silo/> . If you need more information, send an email to: [silo@bom.gov.au](mailto:silo@bom.gov.au)

Weather variables that are monitored and modelled include temperature, relative humidity, rainfall, wind speed and wind direction in the coming days. The website is very flexible and allows users to view general trends or detailed models for their area.

To access the service, users should log on to the BOM SILO website (address above) and then request the level of detail and type of information that is required. An example of how to use the website is as follows:

- Using the 'customised' meteogram setting, select the 'GASP' model for the general 7 day outlook,
- Then check the 'MESOLAPS' model for the maximum inclusion of local effects (but hence also shortest time period).

Of all the weather forecast variables, wind is the most location-dependent e.g. where are the local hills/valleys/trees/any other obstructions sited near the spray location will have the most effect. Therefore, meteograms will be better on 'strong wind' days and light wind days will be more dependent on local effects.

**Meteograms should only be used to look at the expected trends in weather.** Meteogram outlooks come straight from the computer model and are 'untouched' by human hands. They are separate to the official Bureau forecasts and warnings, (see below) which are developed from a range of guidance material combined with local forecasters' expertise.

Refer to the Bureau's web site at <http://www.bom.gov.au/> for the latest official forecasts and warnings, or the 'Weather by Fax' service on pollfax 1902 93 5200 ('quick reference' guide). The information pages on this site provide a complete description of all the Bureau's agricultural services.

For help with forecasts and warnings, aviation briefings (24 hrs), or climate data and information (9-4pm), try the Bureau's Regional Office in your capital city (see contact details below). Some Bureau of Meteorology field offices can also provide information – check telephone directory for your nearest BOM office. Most of these offices operate weather-watch radars which provide up to date images of areas of rainfall. These are updated every ten minutes and the last four images from each radar are freely available on the Bureau's web site. Also available are the current observations from the Bureau's network of automatic weather stations. These are updated hourly and can be used in conjunction with the radar images to assess how the forecast conditions are affecting your area.



## Bureau Regional Offices

### New South Wales

PO Box 413  
Darlinghurst 2010  
NSW

Tel: (02) 9296 1555  
Fax: (02) 9296 1567

### Queensland

GPO Box 413  
Brisbane 4001  
QLD

Tel: (07) 3239 8700  
Fax: (07) 3220 0221

### Northern Territory

PO Box 40050  
Casuarina 0801  
NT

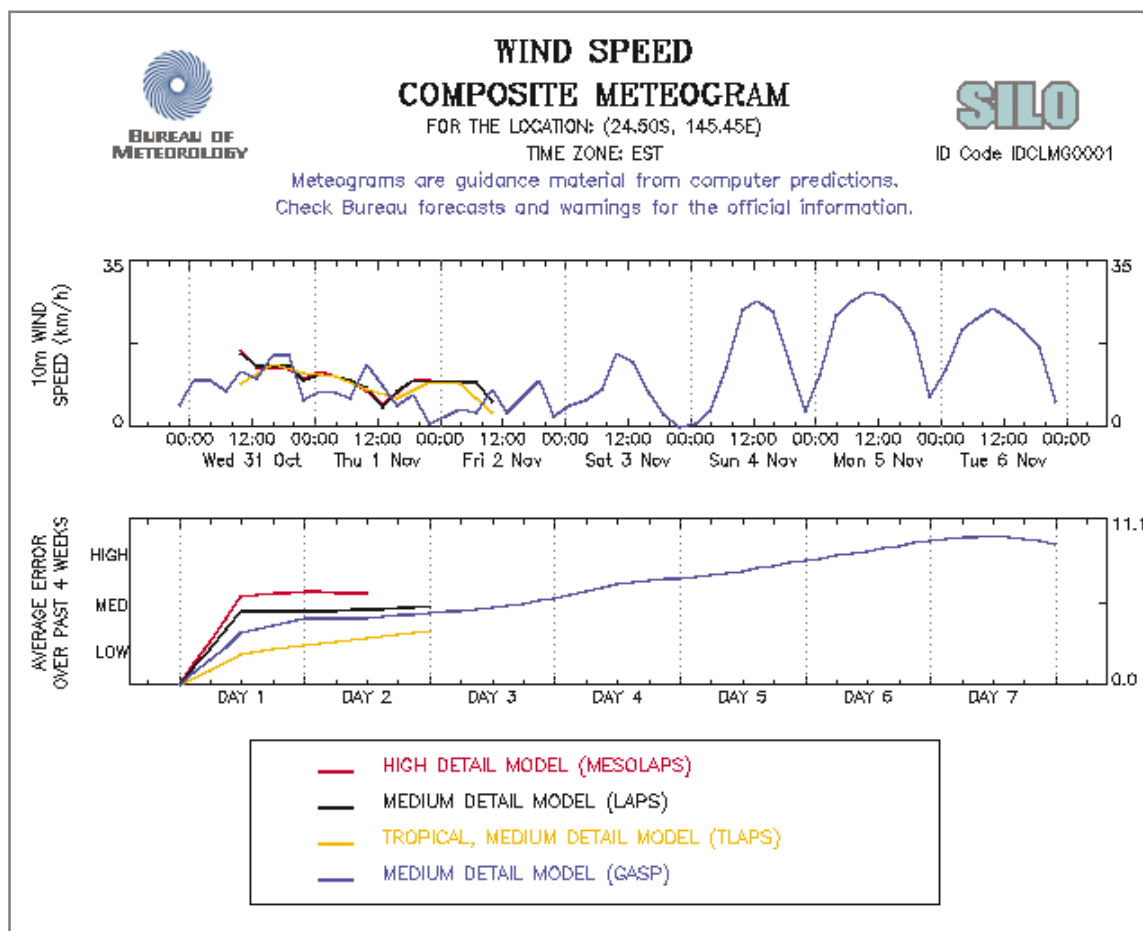
Tel: (08) 8920 3800  
Fax: (08) 8902 3802

### Western Australia

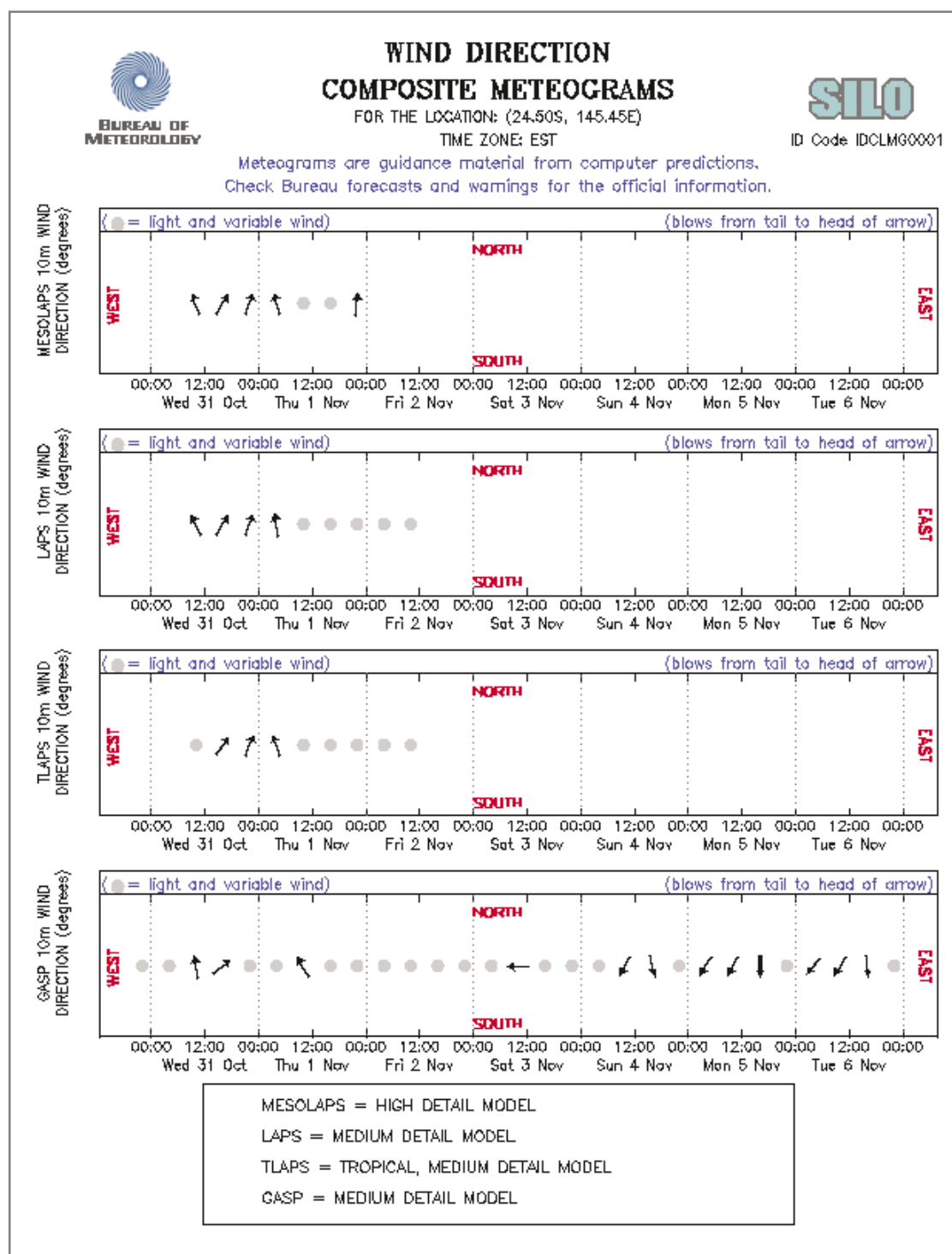
PO Box 1370  
West Perth 6872  
WA

Tel: (08) 9263 2222  
Fax: (08) 9263 2233

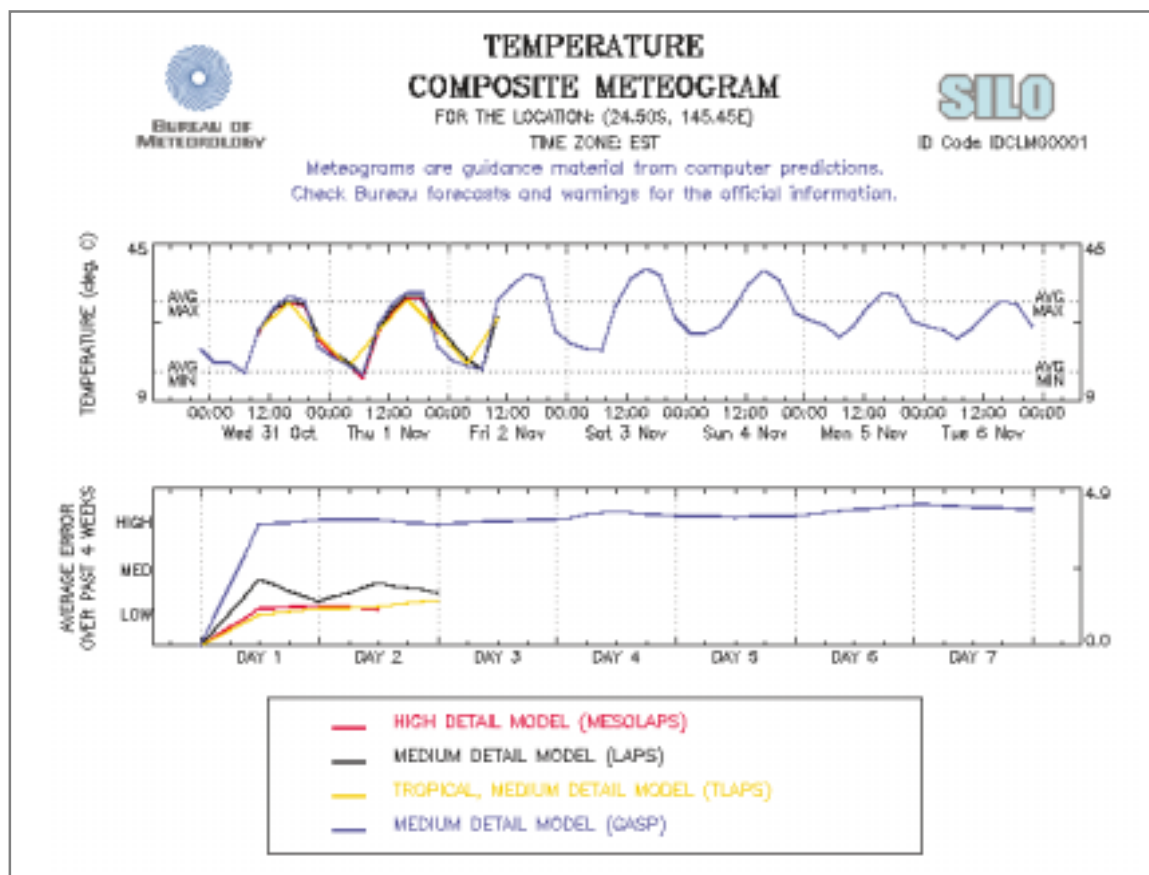
#### A5-1. Composite meteogram - Wind speed.



## A5-2. Composite meteogram - Wind direction.



### A5-3. Composite meteogram - Temperature.



### A5-4. Composite meteogram - Relative humidity.

