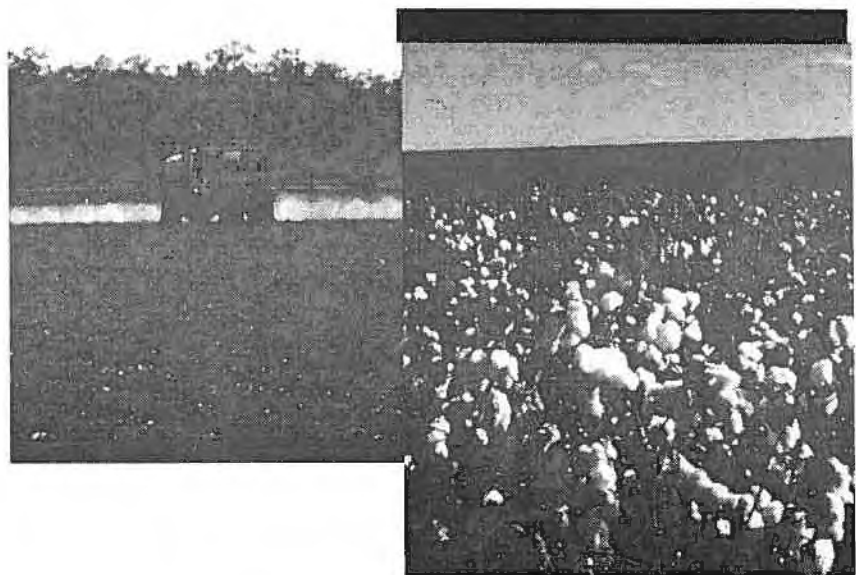
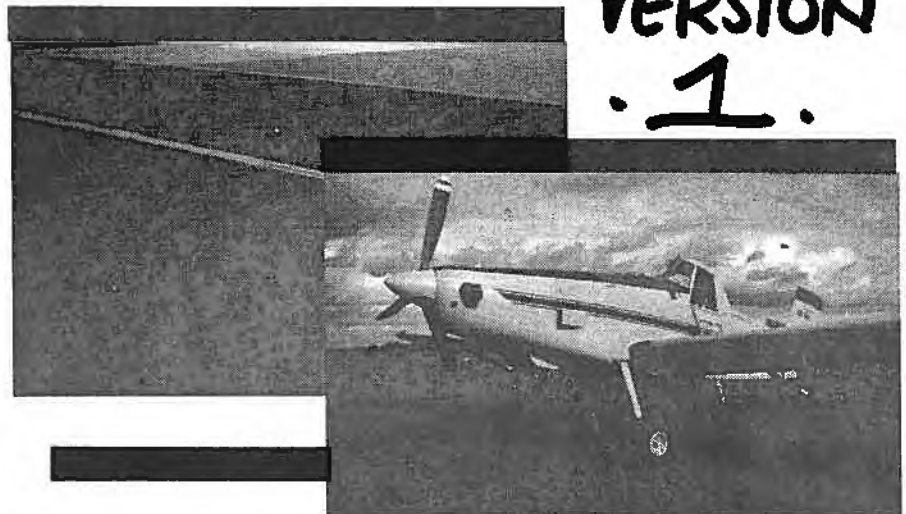


SPRAYpak

VERSION
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THE UNIVERSITY
OF QUEENSLAND
GATTON COLLEGE

produced by

The Centre for
Pesticide Application
& Safety (C-PAS)

on behalf of

The Cotton Research and
Development Corporation



C.R.D.C.

December 1994
reprinted November 1998

The Cotton Growers Spray Application Handbook

SPRAYpak

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This booklet is a guide only. The correct choices of chemical, and the rate and method of application are the responsibility of the user.

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CONTENT

Content.....	i-iv
Foreword.....	v

SECTION A1—Pest Management

Authors: John Whitehead, Peter Hughes and Joe Rickman

Introduction.....	3
1. Target identification and biology.....	3
1.1 Crop growth and thresholds.....	4
1.2 Chemical behaviour.....	4
Further Reading.....	5

SECTION A2—Ground application of cotton sprays

Authors: Peter Hughes and Joe Rickman

Introduction.....	9
1. Droplet size.....	9
2. Spray application equipment for ground use.....	11
2.1 Hydraulic boom sprayers.....	11
2.2 Nozzle types fitted to hydraulic booms.....	12
2.3 Controlled droplet application or CDA boom sprayers.....	14
2.4 Air shear boom sprayers.....	14
2.5 Air assisted boom sprayers.....	15
3. Ancillary machine parts.....	15
4. The calibration of boom spray equipment.....	17
4.1 Static Calibration Method.....	17
5. Spraying setup summaries.....	21
6. Cleaning and decontamination of equipment.....	25

SECTION A3—Safe handling and application of pesticides

Authors: John Whitehead, Peter Hughes and Joe Rickman

Introduction.....	29
1. Responsibilities towards people.....	30
1.1 Safe handling.....	30
1.2 Poisoning.....	30
1.3 Protection—know each pesticide.....	30
1.4 Personal protective equipment (PPE).....	32
1.5 Mixing the pesticide.....	32
1.6 Handling and storage.....	32
1.7 People management and safety.....	33

2.	Responsibilities to livestock and crops.....	34
2.1.	Safe application of pesticides.....	34
2.2.	Types of spray drift.....	34
2.3.	Reducing spray drift.....	35
2.4.	Safe distances and buffer zones.....	35
2.5.	Weather conditions.....	35
2.6.	Communication.....	37
3.	Responsibilities and the environment.....	38
3.1.	Susceptibility of native flora to spray drift herbicide damage.....	38
3.2.	Chemical fate processes.....	39
3.4.	Disposal and dealing with accidental spills.....	41
3.5.	Dealing with spills.....	42
3.6.	Efficient strategic use of pesticides.....	42
4.	References.....	43
	Appendix A3-1:How to properly rinse empty containers.....	44
	Appendix A3-2:Disposal of farm chemicals.....	46

SECTION B1—Droplet generation and behaviour

Authors: Robert Battaglia and Gary Dorr

Introduction.....	49
1. Droplet generation.....	49
1.1 The birth of droplets.....	50
1.2 Droplet transmission.....	51
1.3 Droplet capture.....	52
1.4 Droplet size.....	54
1.5 Droplet size measurement and recovery.....	56
1.6 Water and oil sensitive paper.....	57
1.7 Advanced analytical techniques.....	57
1.8 Laser techniques.....	58
1.9 Fluorometric analysis.....	58
1.10. Image analysis.....	59

SECTION B2—Meteorology and spraying

Author: Nicholas Woods

Introduction.....	63
1. Horizontal wind speed and direction.....	63
1.1. Turbulence.....	65
1.2. Local wind effects.....	66
2. Vertical air movement (stability).....	66
2.1. Air movement and spraying.....	67
3. Temperature.....	68
4. Relative humidity.....	69
5. The influence of weather conditions on spraying.....	70

SECTION B3—Pesticide formulations and selections*Author: John Whitehead*

Introduction.....	73
1. The range of pesticides available.....	73
2. Formulations.....	73
2.1. Current trends.....	73
2.2. Cotton herbicide formulations.....	74
2.3. Cotton insecticide formulations.....	75
2.4. Mixing and applying cotton chemicals.....	76
2.5. The use of adjuvants.....	77
2.6. Using more than one chemical together.....	77
2.7. Strategies with chemicals.....	78

SECTION B4—The use of aircraft for cotton pesticide application*Author: Nicholas Woods*

Introduction.....	81
1. Aircraft types.....	81
2. Application equipment.....	82
3. Aerial application technology.....	83
4. Placement spraying.....	84
5. Wide swath (ULV) spraying.....	85
6. Extended flight lane separations.....	87
7. Aircraft operating conditions.....	87

SECTION B5—Maximising the effectiveness of aircraft*Author: Nicholas Woods*

Introduction.....	91
1. Application windows.....	91
2. Marking.....	92
3. Biological buffer zones.....	93
4. Drift control.....	93
5. Future developments.....	94
5.1. Global positioning systems (GPS).....	94
6. Research and development.....	94

SECTION B6—Extension, information and training

Author: John Harden

Introduction.....99

1. Legislation.....99

2. Label interpretation.....99

3. Safety.....100

4. Application.....100

5. Integrated Pest Management (IPM) strategies.....100

6. Record keeping.....100

7. Delivery of the Accreditation Program.....101

 7.1 General comments on the Accreditation Program.....101

8. Calibration.....101

9. Use of information.....102

 9.1 Extension and communication.....102

10. Technical understanding.....102

11. Additional training & information.....103

 Further Reading.....103

FOREWORD

It gives me pleasure to introduce this first edition of **SPRAYpak**, the Cotton Growers' Spray Application Handbook. Initiated by the Cotton Research and Development Corporation and compiled using the resources of the Centre for Pesticide Application & Safety, The University of Queensland Gatton College, the publication is designed to introduce cotton growers to principles behind the sound and safe application of pesticides.

The handbook is divided into two parts and nine sections. It is anticipated that growers will want to refer more frequently to sections on ground spraying technology, safety, handling and application. This material has been compiled together in the front of the handbook as Part A. In Part B, sections on meteorology, nozzle technology and the use of agricultural aircraft in cotton production are provided which discuss relevant background material in more detail.

We hope that this manual, based largely on the results of research carried out in the Australian cotton industry, will be a relevant and useful guide for growers and help develop more sustainable cotton production practices in the 1990's.

Nicholas Woods
Director C-PAS
November 1994

SECTION A1

Pest Management

PEST MANAGEMENT

Introduction

As a young plant cotton is a poor weed competitor and is vulnerable to a wide range of insect and mite pests throughout its growth. Effective pest management in this crop requires a clear understanding of pest thresholds and the action to be taken when these are reached. This entails a knowledge of both the identification and biology of the crop's pests plus the characteristics and mode of action of the pesticides available for their control. Once the target has been identified, the correct delivery system can be selected to ensure sound pest management and to minimise impact on the environment.

1. Target identification and biology

A pest species can only be defined as a target for a chemical spray with competent identification and a thorough understanding of the pest's biology.

(i) Insects

About thirty species of insects and mites are able to cause economic damage to cotton in Australia. However, the number of regular, serious economic pests is limited to about five species: two *Heliothis* 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 *Heliothis* and mite control, there should be close adherence to the guidelines of the Insecticide Resistance Management Strategy. For *Heliothis* in particular, the species composition within each management unit should be determined with the LepTon™ Test Kit to ensure that the appropriate pesticides are selected when the resistant species, *H. armigera*, is significant (Forrester, 1994; Forrester *et al.*, 1994, Shaw, 1994).

(ii) Weeds

Weed control, including the use of herbicides, accounts for up to 10% of the total variable costs of growing cotton (McMillan, 1988). 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.

1.1 Crop growth and thresholds

Crop growth rate can affect pesticide timing, particularly for insecticides which 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 and canopy size can affect the set-up of application equipment. Crop growth stage can affect the choice and timing of pesticides, particularly herbicides.

One of the most basic foundations of sound pest management is the principle that a pesticide application is not justified until the target has been clearly defined.

Thresholds are used particularly where the application of insecticides and miticides are the most likely control options. The thresholds 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).

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.

1.2 Chemical behaviour

An important part of the pest management equation is knowledge of the way a pesticide does its work and how it behaves in the environment after leaving the spray application system. Using the correct nozzles on the application system to produce the correct droplet size and obtain a good plant coverage is normally crucial for good management. Equally important to the deposition of the pesticide on the target plant is a knowledge of the processes by which the pesticide being used can impact on the general environment and how this can be minimised.

Further Reading

Insecticide Resistance Strategy

Forrester, N., Anderson, I., Howie, B., Fitt, G., Glover, P., Pyke, B., Wilson, L., 1994, Insecticide Resistance Management Strategy Cotton 1994/95.

Information brochure published by: Australian Insecticide Resistance Action Committee (AIRAC) and the Cotton R & D Corporation.

Copies available from Technology Resource Centre, Myall Vale. Contact David Larsen, telephone (067) 991 500.

LepTon™ Test Kit

Forrester, N., 1994, Guidelines for using the LepTon Test Kit, Aust. Cottongrower 15 (5): 18–21 September – October .

Insect and Mite Identification

Forrester, N. W., and Wilson, A. G. L., 1988, Insect pests of cotton, NSW Agriculture Agfact P5.AE.1 17pp.

Copies available from Technology Resource Centre, Myall Vale. Contact David Larsen, telephone (067) 991 500.

Weed Control

Mc Millan, M. G., 1988, Weed control in cotton, NSW Agriculture Agfact P7.2.2 12pp.

Copies available from Technology Resource Centre, Myall Vale. Contact David Larsen, telephone (067) 991 500.

Thresholds and General Cotton Pesticide Information

Shaw, A. J. 1994, Cotton Pesticides Guide 1994–1995, NSW Agriculture.

Copies available from Technology Resonrce Centre, Myall Vale. Contact David Larsen, telephone (067) 991 500.

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SECTION A2

**Ground application
of cotton sprays**

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RECORDS

RECORDS

GROUND APPLICATION OF COTTON SPRAYS

Introduction

Having determined the correct time and dose of a selected pesticide for a threshold action, the grower then has the engineering task of delivering the spray efficiently to the pest target. This involves using a sprayer which is set up to

- deliver droplets consistently of the right size range to be captured by the chosen target;
- deposit the droplets evenly on the target;
- minimise off-target movement and deposition of droplets carrying the chemical active constituent.

This section will discuss achieving these aims.

1. Droplet size

Spray equipment can be adjusted to produce droplets within a desired range suited to varying targets. The following table sets the normal parameters for 'small' to 'large' droplets and indicates the size to target relationship for best results.

Table A2-1. Droplet size classes

Class	Size	Uses
small droplets	<150 μm^*	insecticide fungicide
medium droplets	150 to 250 μm	insecticide herbicide (contact)
large droplets	> 250 μm	herbicides (residual)

* there are 1000 μm in a mm

The influence of size on droplet physical behaviour can significantly affect the efficiency with which a target is reached by a chemical spray.

Some examples of this aspect are summarised in Table A2-2 and include:

(i) 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 upper most parts of the plant canopy.

(ii) Evaporation risk

Small droplets will evaporate rapidly under hot dry conditions leading to rapid degradation of the active being applied and its possible movement off target.

(iii) **Drift potential**

Small droplets pose the highest risk of spray drift. Under normal spray conditions large droplets will only be moved sideways by the prevailing wind but will not move large distances.

(iv) **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. (Table A2-3 indicates the desirable droplet coverage densities for different pesticides).

(v) **Gravity effects**

As a droplet increases its size towards the desirable range for herbicides (200 µm+) so it becomes increasingly subject to gravitational influence. As this influence rises (with size) 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 A2-2. The influence of droplet size on physical behaviour factors

	Droplet size		
	Small	Medium	Large
Canopy penetration	high <-----> low		
Evaporation risk	high <-----> low		
Drift potential	high <-----> low		
Coverage/volume	high <-----> low		
Inertia/gravity effect	low <-----> high		

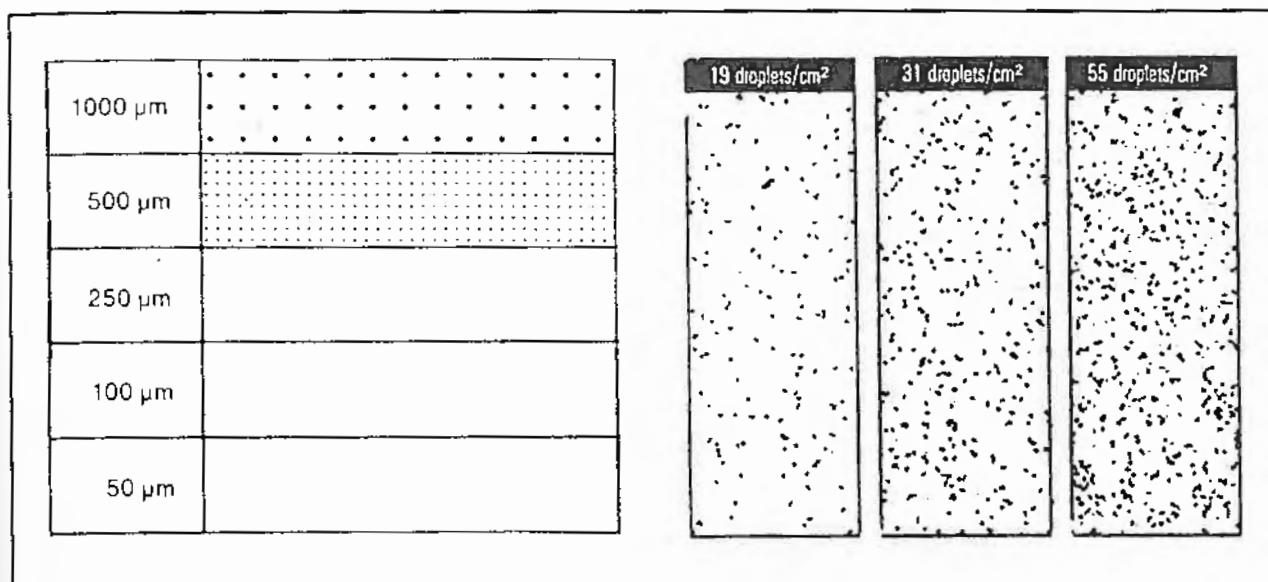
Table A2-3. Desirable droplet coverage densities for pesticides

Product	No. of Droplets/cm ²
Insecticide	20-30
Herbicide	
pre-emergent	20-30
post-emergent	30-40
Fungicides	
contact	50-70
systemic	20-30

Figure A2-1 compares droplet sizes from the clearly visible 1000 micrometres or microns (µm) to those invisible to the naked eye (50 µm) and also compares actual deposits on water sensitive paper ranging from 19 to 55 droplets/cm².

Figure A2-1. Comparative droplet sizes
(Source: Hoechst and Spraying Systems)

Droplet density using water sensitive paper
(Source: Ciba)



2. Spray application equipment for ground use

At present cotton crops are being sprayed by four different types of ground spray machines. All can be used with success.

- (i) **The conventional hydraulic boom sprayer;**
- (ii) **controlled droplet applicator or 'CDA' boom sprayers;**
- (iii) **air shear boom sprayers;**
- (iv) **air-assisted sprayers.**

2.1. Hydraulic boom sprayers

Hydraulic pressure is the most common method of applying pesticides. The system is used on a range of equipment and situations due to its simplicity and flexibility.

To produce droplets, liquid is forced under pressure through a small hole (orifice). A thin sheet is formed. This sheet becomes unstable and disintegrates into spray droplets. A range of droplet sizes is produced due to the uncontrolled nature of the disintegration.

The size of droplets produced depends on the pressure, orifice size and orifice design. Flow rate depends on orifice size and pressure.

In general droplet size decreases when:

- orifice size decreases
- pressure increases
- fan angle increases

Advantages:

- Equipment components are relatively simple.
- Equipment can be tailored to individual situation, i.e. row width.
- Simple change in operating parameters (i.e. nozzle type, pressure) to change between herbicides and insecticides.
- Range of droplet sizes gives a 'shotgun' approach for different targets.

Disadvantages:

- Some nozzles will wear rapidly, so require regular replacement.
- The wide spectrum of droplet sizes may result in droplet wastage due to drift of small droplets and run-off of large droplets.

2.2. Nozzle types fitted to hydraulic booms

Nozzles are precision spray machinery parts which directly influence the spray produced dependent on their design and state of wear. The main types available include:

Cone nozzles

Characteristically these nozzles produce a cone-shaped pattern of spray droplets of a size range best suited to the application of insecticides and fungicides. There are so called 'hollow' cones and 'solid' cones but only the former are recommended because they produce an even size range of droplets with small variation in diameter.

The cone nozzle functions as the result of spray liquid being forced through slots in a 'swirl' plate into a swirl chamber which leads onto the outlet orifice. The design of the swirl plate slots and depth of the swirl chamber influences the resulting spray in the following manner:

To decrease droplet size and spray angle:

- ⇒ **Reduce orifice size**
- ⇒ **Decrease swirl slots**
- ⇒ **Shorten the length of the swirl chamber**
- ⇒ **Raise the hydraulic pressure**

Cone nozzle examples are Spraying Systems TC and Delavan HB.

Fan nozzles

The patterns produced by these nozzles are, as the name suggests, fan-shaped and spray application through them can be likened to a paint-brush operation.

They function as the result of liquid being forced into a nozzle chamber leading to a rectangular or lens shaped orifice of pre-determined size.

(i) **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 the banded application of herbicides.

(ii) **Flat or tapered fan nozzles**

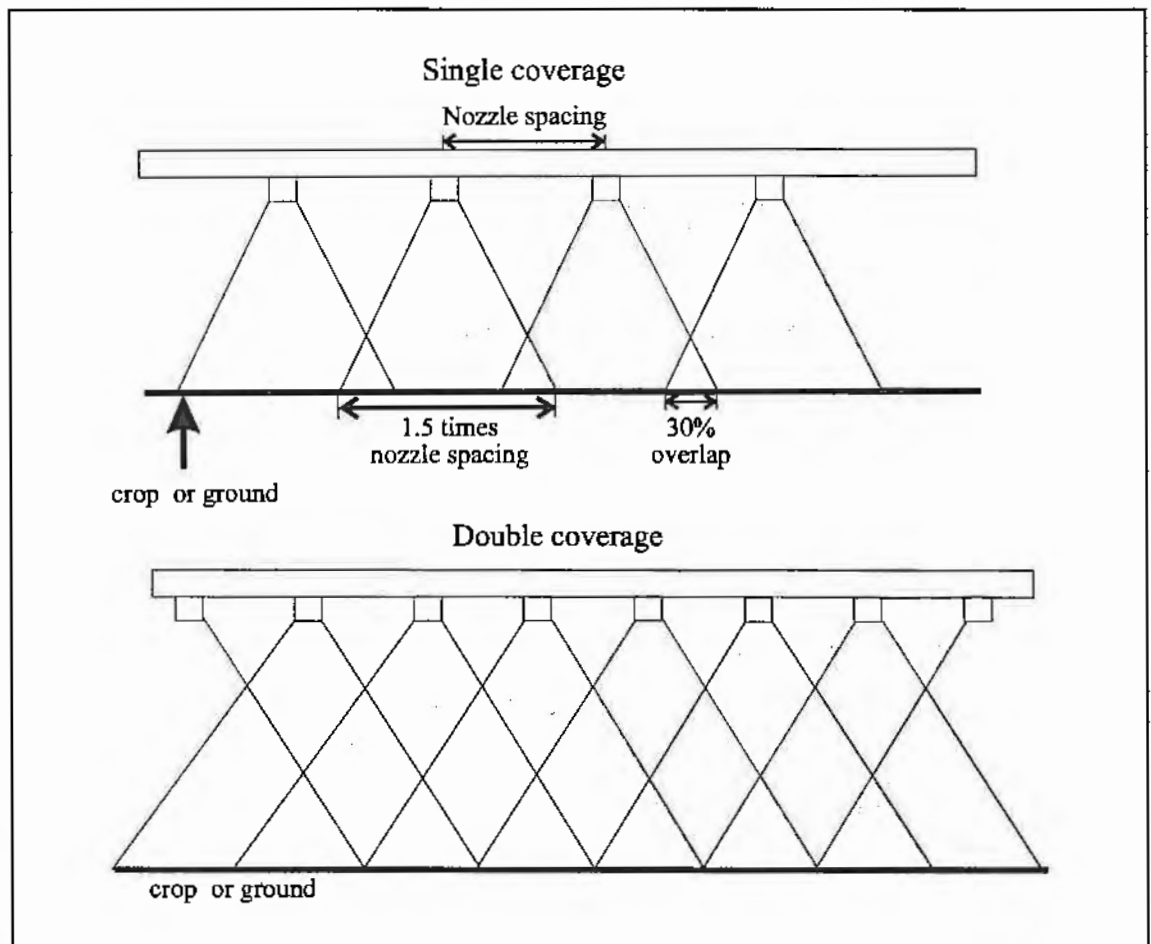
These nozzles have an orifice which ends in a point at either end of its width which results in a lighter droplet distribution as the two edges of the spray swath are approached. Even distribution is attained by allowing adjoining nozzles on a boom to complement each other with a 30% overlap. The correct overlap can be achieved by matching the fan angle designed into the nozzle and height above the spray target as shown in Table A2-4 below.

Table A2-4. Flat fan nozzle heights (above the target)

Fan angle	Single coverage	Double coverage
80°	460 mm	920 mm
110°	250 mm	500 mm

In addition to overlap, the nozzles are offset at 10–15° from the direction of travel of the boom to avoid spray pattern interference between nozzles.

Figure A2-2. Single and double coverage



(iii) **Low pressure 'L.P.' and low drift nozzles**

These nozzles produce more large droplets and less small droplets that may drift off target. By manipulating pressure and design the idea is to reduce drift but this requires a higher application volume to ensure adequate target coverage.

Some examples include:

Low pressure SPRAYING SYSTEMS LP

DELAVAN XR LFR

SILVAN LP

Low drift SILVAN LODRIFT

DELAVAN RF

2.3 **Controlled droplet application or CDA boom sprayers**

Most commercial C.D.A. sprayers use centrifugal energy as the basis 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 Figure B 1-2). 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. If the flow rate is too high for the rotation speed, a wide range of droplet sizes is produced.

Advantages:

- Application volumes can be decreased due to the narrow droplet spectrum.
- Increased number of droplets of optimum size.

Disadvantages:

- Increased expertise required to set up and operate.
- Mechanical failure due to more complex system, i.e. hydraulic or electric motors, discs or cages.

Characteristics of CDA:

To decrease droplet size:

- decrease flow rate
- increase rotation speed.

Commercial examples: Micromaster Sprayer, Technoma Girojet

2.4 **Air shear boom sprayers**

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

With the high air velocity care must be taken when setting up and operating the equipment. Bounce of the air stream 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.

- | | |
|---------------------------------|---------------------------------------|
| To make droplets smaller | 1. increase air speed |
| | 2. lower pesticide flow rate |
| To make droplets larger | 1. run blower engine at half throttle |
| | 2. increase liquid flow rate |

An example of a machine is the **Silvan Turbomiser Boom**.

2.5 Air assisted boom sprayers

The principle with this delivery system is to use an air stream operating at half the speed of a mister (100–170 kph) to carry droplets generated by either hydraulic or CDA means towards a plant target and then to replace the air surrounding the target with the chemically charged volume. Usually 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.

Examples of available machines include:

HARDI TWIN

HARDI MINIVARIANT

NUFARM AIRSPRAY

DEGANIA

MICROMASTER

3. Ancillary machine parts

Pressure gauges

The usefulness of a gauge depends on its ease of being read and this means having a scale appropriate to its range of operation and being damped with glycerine to cut out vibration. A range of 275 kpa to 700 kpa is adequate.

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.

Filters

A good filter system that is regularly cleaned will ensure fewer stoppages due to blocked nozzles. Fan nozzles are particularly sensitive to blockages. Filters can be fitted in line where they should have enough capacity to cope with a few hours work and carry a finer mesh (120) than any nozzle filters that may be fitted. Filters ensure smoother spray operations and reduce wear and tear in the spray system caused by abrasion.

Check valves

Non-drip nozzle assemblies are generally available and their use recommended. It should be noted that 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 hormones'. Under these circumstances replace all diaphragms before spraying cotton.

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 applied by a switch activating a solenoid.

Markers

A marking system is essential if 'overlapping' and 'stripping' are to be minimised. The type of marker needed depends on the boom spray design and environmental requirements. The following types of markers are available.

(i) Foam markers

Foam (blob dobber) markers are widely used by both farmers and contractors. The white colour is suitable for in-crop and bare-fallow spray operations, however 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. See following section on foam marker construction and operation.

(ii) Paint markers

Water-based paint has been used as a replacement for the traditional silver streak (diesel base) 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 dead sorghum.

(iii) 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. Make sure the disc throws soil away from the swath being sprayed.

4. The calibration of boom spray equipment

It is only through accurate calibration that the grower can be sure the correct effective dose of pesticide is being applied. Raingrown cotton has a varying population per hectare which reflects anticipated available moisture. The three main effective row spacings of 1 m (solid), 1.5 m (single skip) and 2 m (double skip) have to be taken into account when calibrating.

4.1 Static Calibration Method

- Check all nozzles. Collect the output from every nozzle for a given time, for example, 30 seconds, and replace any that vary by more than 10% from the manufacturer's specification. Calculate the average flow per nozzle in L/min.
- Note number of nozzles set up per row of cotton; it may vary from 1 to 5, depending on stage of season.
- Calculate speed:
 - (i) Select rpm and gear to give required forward and pto speed.
 - (ii) Measure time to cover 100m run on ground surface to be sprayed.
 - (iii) Repeat several runs and average the times.

$$\text{Speed (km/hr)} = \frac{\text{Run length (m)} \times 3.6}{\text{Time (sec)}}$$

- Determine application rate per paddock ha. Application rate per paddock ha is determined by focussing on the output from a nozzle(s) over one row unit. The width of this row unit is influenced by the planting configuration used.

Table A2-5: Effective Row Width

Planting Configuration	Effective Row Width (m)
Solid plant	1.0
Single skip	1.5
Single skip + Tramline	1.6
Double skip	2.0

$$\text{Application rate/paddock ha (L/ha)} = \frac{\text{Average flow / nozzle (L/min)} \times \text{no. of nozzles / row} \times 600}{\text{Speed (km/hr)} \times \text{effective row width (m)}}$$

Note 1:

The number 600 is a conversion factor, to allow for changing min to hr, km to m, m² to ha. For example:

$$\frac{60 \times 10,000}{1000}$$

Note 2:

If a mixture of nozzle types is being used for a row, add their individual average flow rates, rather than multiplying the Average flow/nozzle by the number of nozzles/row.

- Determine paddock area per tankful

$$\text{Paddock area/tankful (ha)} = \frac{\text{Tank capacity (L)}}{\text{Application rate / paddock ha (L/ha)}}$$

Conversion of PADDOCK area to SPRAYED area

At this stage, it is necessary to convert paddock area to sprayed area. Chemical recommendations and water volumes are always expressed in relation to sprayed area. Paddock area is always a larger value than sprayed area.

- Determine the band factor. Allowance needs to be made for changes in the plant's growth form and leaf area during the growing season, and hence the percentage of any planted cotton row to which spray is applied. In the determination of this band factor, both the height of the crop and the planting configuration need to be considered, plants in skip configurations tending to be larger in overall size. The band factor also incorporates the varying percentage of a paddock sprayed, depending on what planting configuration is used.

Table A2-6: Band factor for varying crop height and planting configuration

Crop Height (cm)	Solid Plant	Single Skip	Single Skip + Tramline	Double Skip
10	0.25	0.15	0.15	0.125
15	0.30	0.20	0.20	0.15
30	0.40	0.25	0.25	0.20
40	0.50	0.35	0.30	0.25
60	0.75	0.50	0.45	0.40
80	0.90	0.60	0.55	0.50
90	0.95	0.70	0.65	0.55
100	1.00	0.75	0.70	0.60

- Calculation of sprayed area per tankful

$$\text{Sprayed area/tankful (ha)} = \text{Paddock area/tankful} \times \text{band factor}$$

$$\text{Application rate/sprayed ha (L/ha)} = \frac{\text{Tank capacity (L)}}{\text{Sprayed area / tankful (ha)}}$$

Example 1 (Part A)

Determine the sprayed area of cotton treated with a boomspray when the following conditions apply:

$$\begin{aligned} \text{Flow per nozzle (L/min)} &= 0.4 \\ \text{No. nozzles per row} &= 3 \\ \text{Double skip planting} & \\ \text{Tank capacity (L)} &= 1200 \end{aligned}$$

$$\begin{aligned} \text{Speed (km/hr)} &= \frac{\text{Run length (m)} \times 3.6}{\text{Time (sec)}} \\ &= \frac{100 \times 3.6}{40} \\ &= 9 \text{ km/hr} \end{aligned}$$

$$\begin{aligned} \text{Application rate/paddock ha} &= \frac{\text{Flow per nozzle} \times \text{no. of nozzles / row} \times 600}{\text{Speed} \times \text{effective row width}} \\ &= \frac{0.4 \times 3 \times 600}{9 \times 2} \\ &= 40 \text{ L/ha} \end{aligned}$$

$$\begin{aligned} \text{Paddock area/tankful (ha)} &= \frac{\text{Tank capacity}}{\text{Application rate}} \\ &= \frac{1200}{40} \\ &= 30 \text{ ha} \end{aligned}$$

At the time of spraying, crop conditions were:

$$\begin{aligned} \text{Plant configuration} &= \text{double skip} \\ \text{Plant height} &= 60 \text{ cm} \\ \text{From Table A2-6, band factor will be } &0.4 \end{aligned}$$

$$\begin{aligned} \text{Sprayed area/tankful} &= \text{Paddock area/tankful} \times \text{band factor} \\ &= 30 \times 0.4 \\ &= 12 \text{ ha} \end{aligned}$$

Determination of amount of chemical to be added to tank

Chemical recommendations on labels are always given on a SPRAYED ha basis.

$$\text{Quantity of chemical needed/tankful (L)} = \text{Sprayed area/tankful (ha)} \times \text{chemical recommendation}$$

Example 1 (Part B):

Label recommendation for product is 2.0 L/ha

Using rates per sprayed area (ha)

Amount of chemical to be added to 1200 L tank

$$\begin{aligned} &= \text{Sprayed area/tankful (ha) x chemical rate} \\ &= 12 \text{ ha x } 2.0 \text{ L/ha} \\ &= 24 \text{ L} \end{aligned}$$

Alternate method – using rates per paddock area (ha)

- Determine paddock area per tankful (method as above): 30 ha
- Determine amount of chemical to be added per tankful

Chemical rate/paddock area = Chemical recommendation on label x band factor

$$\begin{aligned} &= 2.0 \text{ x } 0.4 \\ &= 0.8 \text{ L/ha} \end{aligned}$$

Amount of chemical to be added to 1000 L tank

$$\begin{aligned} &= \text{Paddock area/tankful x chemical rate/paddock area} \\ &= 30 \text{ x } 0.8 \\ &= 24 \text{ L} \end{aligned}$$

Note: To determine the water volume per sprayed hectare, if required, for example, to check label water volume recommendations.

$$\begin{aligned} \text{Application rate/sprayed ha} &= \frac{\text{Tank volume}}{\text{Sprayed area / tankful}} \\ &= \frac{1200}{12} \\ &= 100 \text{ L/ha} \end{aligned}$$

5. Spraying setup summaries

The following tables provide setup details for various pesticides, application situations and equipment.

Table A2-7. Herbicide application

Preplant application—contact products

System	Nozzle	Pressure kPa	Confg.	Volumes L/ha	Notes
Hydraulic	110-01	300	Broadacre	40-60	
	110-015				
	Low drift	300	Broadacre	50-70	
	Low pressure	150	Broadacre	60-80	
Air Asslet	110-01	300	Broadacre	40-60	<ul style="list-style-type: none"> • Decrease air volume. • Make sure air stream does not bounce off ground surface.
	110-015				
Airshear	Airshear				<ul style="list-style-type: none"> • Not recommended for herbicide.
CDA	-	-	Broadacre	50-60	<ul style="list-style-type: none"> • Technoma[®] units will operate broadacre.

Residual products

System	Nozzle	Pressure kPa	Confg.	Volumes L/ha	Notes	
Hydraulic	110° or 80°	03	250-300	Broadacre	80-250	
		04				
	Low drift	03	300	Broadacre	80-250	
		04				
	Low Pressure	150	Broadacre	80-250		
Air Assist	110° or 80°	03	250-300	Broadacre	80-250	<ul style="list-style-type: none"> • No air or very low. Make sure you cannot feel air bouncing at ground level.
		04				
	Low drift	03	300	Broadacre	80-250	
		04				
	Low Pressure	150	Broadacre	80-250		
Airshear					<ul style="list-style-type: none"> • Not recommended. 	
CDA			Large droplets	80-100	<ul style="list-style-type: none"> • Technoma[®] units will operate broadacre. 	

Table A2-7. Herbicide application (continued)

At planting

System	Nozzle	Pressure kPa	Config.	Volumes L/ha	Notes
Hydraulic	Even 03 04	300	Band behind planter	80-250	• Set height for desired band width.
Air Assist					• Not applicable.
Airshear					• Not applicable.
CDA					• Not applicable.

Directed

System	Nozzle	Pressure kPa	Config.	Volumes L/ha	Notes
Hydraulic	Flat fan 02	250-300		50-70	• Nozzle height and position critical to ensure crop not sprayed. Use flat fan where two nozzles will overlap.
	03				
	Low pressure 02	150		60-80	
	03	250-300		55-70	
	Low drift 02	250-300			
03					
	Even	150-300		50-70	
Air Assist					• Not applicable.
Airshear					• Not applicable.
CDA					• Not applicable.

Shielded

System	Nozzle	Pressure kPa	Config.	Volumes L/ha	Notes
Hydraulic	Flat fan 02	250-300		50-70	• All nozzles produce some drift when using large droplets ↑ volume to maintain coverage.
	03				
	Low pressure	150		60-80	
	Low drift	250-300			
	Even 02	150-300		50-70	
03					
Air Assist					• Not applicable.
Airshear					• Not applicable.
CDA					• Not applicable.

Table A2-8. Crop conditioners

Defoliants

System	Nozzle	Pressure kPa	Config.	Volumes L/ha	Notes
Hydraulic	Flat fan 110°	>500	3/row	100-200	<ul style="list-style-type: none"> Ensure all nozzle spray overlap before reaching the plant.
	02 Cone TX8	>500	5/row	100-200	
Air Asslet	Flat fan	>500		70-140	<ul style="list-style-type: none"> Use highest volume at lowest air speed. At least one outlet/row.
	02 03 Cone TX8	>500			
Airehear				70-140	<ul style="list-style-type: none"> At least one outlet/row.
CDA				40-80	<ul style="list-style-type: none"> Ensure flow rate not too high for units. At least one outlet/row.

Table A2-9. Insecticides

At planting – water injection

System	Nozzle	Pressure kPa	Config.	Volumes L/ha	Notes
Hydraulic	Not applicable		Planting boot	650-1200	<ul style="list-style-type: none"> Effect of water injection often due to its role as a carrier of insecticide or fertiliser. Large ↓ in field efficiency.

In furrow spray

System	Nozzle	Pressure kPa	Config.	Volumes L/ha	Notes
Hydraulic				20-50	<ul style="list-style-type: none"> Band at least 10 cm wide.

Granules

System	Suppliers	Notes
Granule	Gandy Kinze	

Table A2-10. Insecticides—Post plant

Band 0-30%

System	Nozzle	Pressure kPa	Config.	Volumes L/ha*	Notes
Hydraulic	Flat fan 01	>500	1/row	40-100	<ul style="list-style-type: none"> Make sure all nozzles overlap before hitting plant.
	HC TX2-4	300	1-2/row	30-60	
Air Assist	Flat fan 02	>500	1 outlet/row	30-50	<ul style="list-style-type: none"> Aim outlet across and down at the row.
	Cone TX8	>500			
Airshear	Not applicable	Not applicable	1 outlet/row	40-80	<ul style="list-style-type: none"> Direct outlet across the row at 45°. Watch for bounce of spray. Use boom height and downward angle of outlet to minimise bounce.
CDA			1 outlet/row	20	<ul style="list-style-type: none"> Direct outlet across rows at 45°.

Band 30-50%

System	Nozzle	Pressure kPa	Config.	Volumes L/ha *	Notes
Hydraulic	Flat fan 01	>500	3/row	70-150	<ul style="list-style-type: none"> Make sure nozzles overlap before hitting plant.
	HC TX2-4	300	3/row	40-90	
Air Assist	Flat fan 02	>500	1/row	30-50	<ul style="list-style-type: none"> Increase air volume.
	Cone TX8	>500			
Airshear	Not applicable	Not applicable	1/row	40-80	<ul style="list-style-type: none"> Direct outlet across the row at 45°.
CDA				20	<ul style="list-style-type: none"> Direct outlet across rows at 45°.

Band 50-100%

System	Nozzle	Pressure kPa	Config.	Volumes L/ha *	Notes
Hydraulic	Flat fan 01	>500	3/row	70-150	<ul style="list-style-type: none"> Make sure each nozzle pattern overlaps each other before hitting the plant.
	HC TX2-4	300	5/row	50-100	
Air Assist	Flat fan 02	>500	1/row	30-60	<ul style="list-style-type: none"> High air volume. Aim outlet slightly across and down at the row. Allow pattern to spread out before hitting crops. Do not have outlets too close to the row or striping will result.
	Cone TX8	>500			
Airshear	Not applicable	Not applicable	1/row	40-80	<ul style="list-style-type: none"> Direct outlet across the row at 45°.
CDA				20	<ul style="list-style-type: none"> Direct outlet across rows at 45°.

* Note: All volumes refer to L/sprayed ha.

6. Cleaning and decontamination of equipment

No spraying operation is completed until the equipment used has been properly cleaned out and decontaminated from chemical residues. Failure to clean may result in the risk of future contamination and possible crop damage as well as accelerated equipment deterioration.

Different agrochemicals require different treatments and this table is a guide to dealing with the major chemical groups.

Table A2-11. Guide to dealing with decontamination of major chemical groups

Chemical Grouping	Amounts Cleaning Agent per 100 L Water	Instructions
Organophosphates e.g. Lorsban [®] Nuvacron [®] Supracide [®] Carbamates e.g. Lannate [®] Bugmaster [®]	125 g powdered detergent + 1 Litre household ammonia	<ul style="list-style-type: none"> Thoroughly agitate. Flush a small amount through the system in the sprayer overnight. Flush next day with at least two washings of clean water.
Organochlorines e.g. Thiodan [®] Endosulfan	500 g washing soda + 125 g powdered detergent	<ul style="list-style-type: none"> Rinse inside of tank and flush a small amount through the system. Fill and let stand for 2 hours. Flush twice with clean water.
Hormone Type Herbicides a) Water Soluble Formulations e.g. 2,4-D Amine MCPA Banvel [®]	500 g washing soda	<ul style="list-style-type: none"> 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.
Hormones b) Oil Soluble Formulations 2,4-D Ester 2,4,5-T Esters	3 litres Kerosane + 500 g washing soda + 125 powdered detergent	<ul style="list-style-type: none"> Follow procedure above.
Sulfonylureas e.g. Glean Ally Brush Off	350 ml household bleach (35 g/l available chlorine) NEVER MIX BLEACH AND AMMONIA	<ul style="list-style-type: none"> Flush with clean water then follow procedure above. Nozzles and filters should be cleaned separately.

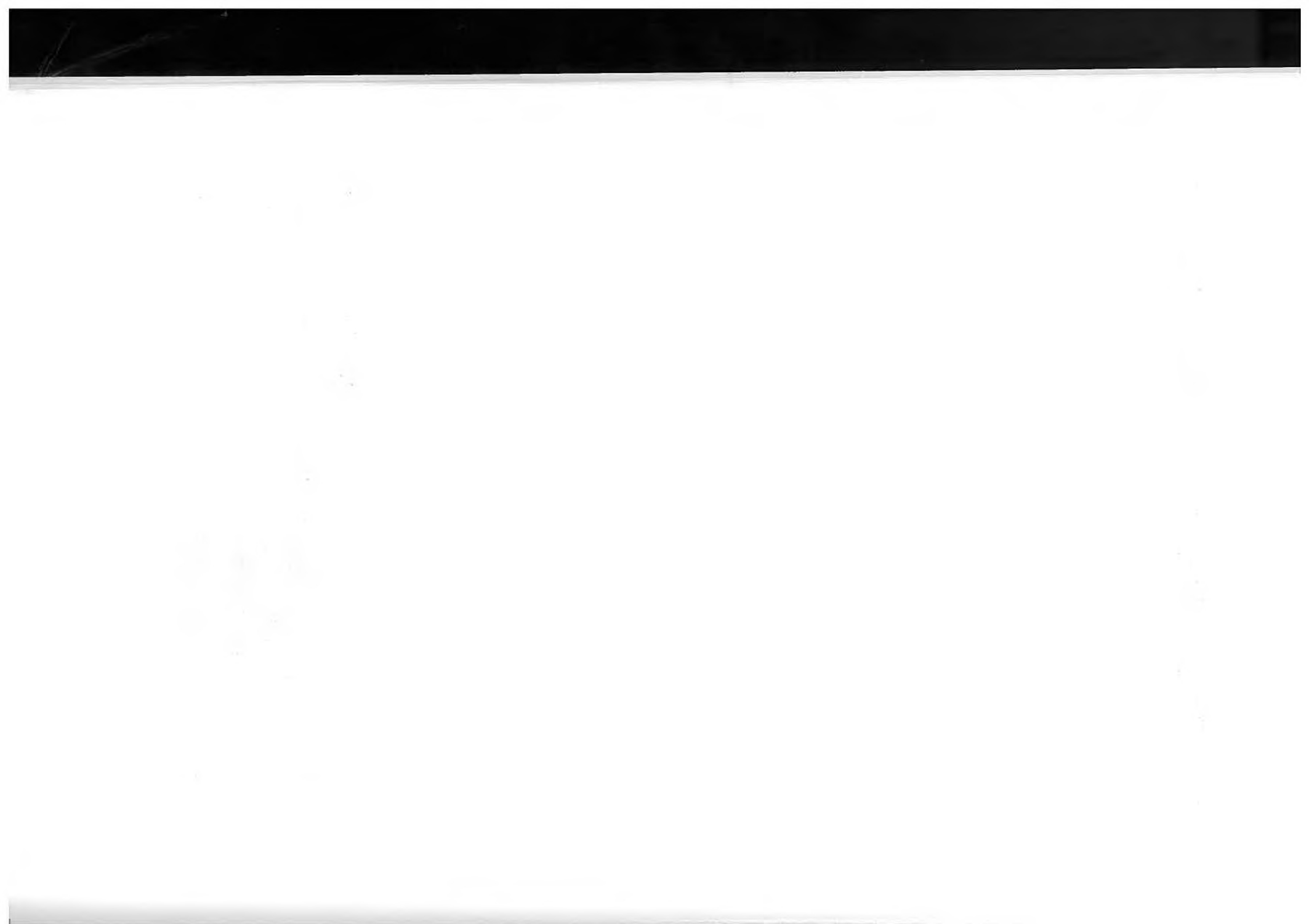
Introduction to the study of the history of the world

The study of the history of the world is a vast and complex field. It involves the study of the events, people, and societies that have shaped the world as we know it today. This study is essential for understanding the present and for predicting the future.

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SECTION A3

**Safe handling and
application of pesticides**



SAFE HANDLING AND APPLICATION OF PESTICIDES

Introduction

Using chemicals brings with it responsibilities in a number of areas that can be conveniently thought of as

- concerning people;
- concerning non-target livestock and crops; and
- the environment.

All are important and spray operations should always be checked to ensure error and accident are avoided.

Pesticides—a definition

A pesticide is a substance used to destroy, prevent, control, attract or repel pests or regulate plant growth. They come in the form of liquid, powder, dust, granules, baits or a gas. Pesticides can be grouped and are referred to according to their purpose.

Pesticides	Purpose
Weedicide or herbicide	• kills weeds or herbage
Bacteriacide	• kills bacteria
Fungicide	• kills fungi
Miticide	• kills mites
Insecticides	• kills insects
Larvicide	• kills larvae (young stages)
Ovicide	• kills eggs of insect or mites
Growth regulator	• changes normal plant growth
Desiccant	• dries up plant leaves and stems
Defoliant	• removes plant leaves without killing the plant

Pesticides range from common everyday things 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, domestic animals and plants.

Commonly a pesticide has three main components which together make up the formulation. These are the active constituent, a carrier or solvent system and a surfactant to facilitate spray solutions or suspensions. All these components must be taken into account for the safe handling of the product.

- the active ingredient—kills the pest;
- the surfactant—acts like a detergent dispersing the active constituent evenly over the target;
- the carrier—stabilises the diluted product and aids coverage and application of the pesticide.

1. Responsibilities towards people

1.1. Safe handling

Recently the Department of Employment, Vocational Education, Training and Industrial Relations issued a "Code of Practice for the Storage and Use of Chemicals at Rural Workplaces". Shortly afterwards the Australian Agricultural Health Unit launched its "Managing Farm Safety" training program which includes a section covering chemical accountability. This section should be seen as harmonising with and complimentary to these initiatives.

1.2. Poisoning

Pesticides can enter the body in three ways:	
Orally	<ul style="list-style-type: none"> • direct by drinking • splashes • while eating or smoking • eating sprayed products • by cleaning nozzles with the mouth
Inhalation	<ul style="list-style-type: none"> • breathing in spray droplets, dust or fumes • hazard is greatest in enclosed buildings
Dermal	<ul style="list-style-type: none"> • absorption through the skin is the most common hazard to users. The risk increases when perspiring or when the skin is broken.

Accidents are usually the result of contamination with the concentrate.

Contamination through splashing and spillage of liquid concentrates and dust from powder concentrates are 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 although care needs to be taken when fixing burst pipes. Consideration should be given to continual exposure to spray drift and when entering sprayed paddocks still loaded with active residues. Cotton chippers especially need alerting to this situation.

If accidental dousing with pesticides occurs, wash thoroughly with soap and water and change contaminated clothing immediately. Wash thoroughly before eating and drinking and change into clean clothes at the end of the job.

1.3. Protection—know each pesticide

The first step in the safe handling and use of chemicals is to know the pesticide.

Before use:

Stop and read the label—it is a legal document

Part of the clearance procedure noted in Section A2 involves review by experts in the National Health and Medical Research Council.

A poison warning on a pesticide label indicates the potential health hazard of a pesticide to the user. A pesticide is classified into one of four categories on the Poison Schedule. The four categories and the accompanying special warning words, are:

- Exempt – no special warning words required
- Schedule 5 – WARNING
- Schedule 6 – POISON
- Schedule 7 – DANGEROUS POISON S7

These red on white background signal words always appear at the top of the label's central panel which bears the trade name.

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'.

MSDS

MSDS stands for **Material Safety Data Sheet** and there is one available for every pesticide and will be supplied **on request** where chemical supplies are obtained. It contains more detail on the physical nature of the product, the dangers associated with accidental exposure to it and how to proceed in the event of an accident. Cotton growers should ensure all employees handling and applying pesticides read the label and have access to the relevant MSDS information.

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 chemicals.

For example as a minimum:

- S5 Wear rubber gloves when handling the pesticide.
- S6 Wear rubber gloves and face shield when handling the concentrates.
- S7 Wear protective waterproof clothing, rubber gloves and an agricultural respirator during all operations including spraying.

Schedule 7 pesticides also have much stricter controls placed on their supply and availability than S5 and S6 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. Pesticide products may appear in more than one schedule if the products contain different concentrations of active ingredient. Amongst the registered cotton chemicals, the ones that need special attention to safety include the carbamates, organophosphates and some of the more active synthetic pyrethroids. All labels however should be carefully followed.

1.4 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 chemicals. General guidelines for PPE and hazard to the environment for common cotton pesticides are available, in wall chart form, from the Australian Cotton Foundation, telephone (02) 319 3677.

Clothing

Cover as much of the body as possible, especially the neck, chest and forearms. Use washable fabric overalls and waterproof clothing if coming in contact with large quantities of pesticides. **WEAR TROUSER LEGS OUTSIDE THE BOOTS.**

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.

Face and eyes

Hard hats, washable hats, 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 date on each cartridge. Ensure the respirator fits well and store safely when not being used.

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 air-conditioners 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 protective clothing for filling and mixing.

1.5 Mixing the pesticide

Where possible eliminate or reduce the operator's contact with the concentrate. This can be done by using closed loading systems as with aircraft or auto filler and concentrate suction spears or hoses.

Take care when opening drums and bags. Bags should always be cut. Chemicals should **NEVER BE STIRRED WITH YOUR HAND OR ARM.**

1.6 Handling and storage

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.

All pesticides should be stored in a locked cupboard, storeroom, shed or enclosure. Herbicides should be stored separately from insecticides and fungicides.

1.7 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 the chemical pest control option safely and effectively. This is very much a horses for courses operation as different situations will call for different priorities. Basics include provision of:

- Safe spray mixing facilities.
- Safe and secure storage of chemical stocks.
- Safe transport of pesticides when required.

Adequate training for all involved in spraying or who are likely to be called upon as backup is a duty of care obligation in 1994. 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—especially towards children and bystanders.
- Knowledge of local emergency procedures.

1.7.1. 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 organo-phosphates or carbamates. Blood tests are of little value for non-accumulating pesticides such as organo-chlorines or pyrethroids as the timing of the tests are critical and the chemicals 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.

Table A3-1. Cotton insecticide chemical groups*

Organo-chlorines	Organophosphates	Carbamates	Pyrethroids	Chitin inhibitors	Synergists	Biologicals
endosulfan dicofol	chlorpyrifos demeton-S-methyl dimethoate phorate profenofos	aldicarb methomyl thiodicarb	alphamethrin bifenthrin cyhalothrin deltamethrin esfenvalerate fluralinate	chlor-fluazuron	piperonyl-butoxide (PBO)	bacillus thuringiensis

* Further information see Shaw, A. J., 1994, Cotton Pesticides Guide, NSW Agriculture (in press).

2. Responsibilities to livestock and crops

Cotton is often produced in mixed enterprise areas consisting of both raingrown and irrigated management regimes. This means there is sometimes the potential for drift damage when an incorrect spray decision might mean significant movement of active to areas outside the designated target. The consequences of these events can be both tragic and expensive.

In the case of livestock, apart from direct contact and possible poisoning

- fodder contamination can occur with delayed effects; and
- water troughs may be polluted.

In addition, care must always be taken to ensure fences and gates preclude livestock entry to treated areas and any disposal sites for containers and washings are securely fenced.

Neighbouring crops will vary in their sensitivity to chemicals. Herbicides and defoliant do damage other crops given movement under certain weather conditions and the utmost care should always be exercised where sensitive crops are known to exist. For example, paraquat and diquat, used as clean up applications before crop emergence, can produce masses of brown necrotic spots on any chlorophyll bearing leaves their droplets contact. Their drift may be undetectable but the consequences can be highly visible.

2.1. Safe application of pesticides

Efficient pesticide application minimises the off-target movement of the chemical whilst still maintaining an acceptable level of pest management. Whilst some off-target movement of pesticides is inevitable, significant losses should not occur if the correct application techniques are employed under favourable environmental conditions.

2.2. Types of spray drift

Two types of drift occur. These are droplet/particle drift and vapour drift, plus combinations of the two.

Droplet/particle drift is the most common form with three types occurring:

- direct wind drift
- thermal drift
- inversion drift

Small droplet size plays a role in all instances. (See Section A2, 1.)

Vapour drift is the movement of volatile components of pesticide during the following application in air currents. These are significant where the volatile component has biological activity which occurs in 2,4-D ester – hence the special restrictions on these chemicals in some mixed-cropping areas.

2.3. Reducing spray drift

Applicators need to be aware of the major factors that contribute to drift. These factors are:

- Weather conditions during and immediately after application.
- Droplet and particle size. This is determined by the application method and equipment used. The use of large nozzles at low pressure reducing drift danger.
- 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.
- Direction of application. Spraying upwards or into a wind increases the risk of drift.

2.4. Safe distances and buffer zones

All droplets travel in the wind currents until they are caught by a target. All spray application is characterised by a peak deposit close to the centre line of application and a downwind tail. The amount of pesticide in the downwind tail is affected by factors such as wind speed, release height, droplet size and the catching efficiency of the surface. Downwind buffer areas have the capacity to catch droplets that move off-target.

Safe distances with respect to drift from spraying operations are entirely dependent on weather conditions and appropriate application techniques. A light wind is highly desirable and essential to carry droplets down into the crop and onto the insect target. A buffer zone of 300 m of crop or 500 m of bare fallow should be adequate for most 'safe' spraying situations.

However, if the conditions are not suitable or equipment is poorly set up and operated, drift can be substantial and safe distances are impossible to define. Under high winds, pesticides can drift several kilometres. Likewise, fine droplets suspended in the air under calm conditions or in hot, dry conditions can drift randomly in response to very minor local influences.

2.5. Weather conditions

(see also section B2 for more detail)

Wind

Avoid strong winds greater than 15 km/hr, or if the wind is in the direction of nearby susceptible crops, homes, sheds, stock or water supplies. Avoid spraying under still or low wind speed situations (less than 4 km/hr). 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 deposit. Wind socks and smoke generators are good indicators of wind speed and direction.

Wind speed

As a guide to estimating wind speed, Table A3-2 is part of the Beaufort Scale of Wind Speeds. Chemical spraying should cease when at No. 3. Effective wind speed meters are available. Dwyer wind speed meters are available from boating shops for under \$50. Davis electronic speed meters (turbometers) are available from Dick Smith Electronics for about \$170.

Table A3-2. Beaufort scale of wind speeds

Beaufort No.	Speed (km/hr)	Description	Guide for Judging
0	less than 1	Calm	<ul style="list-style-type: none"> • smoke rises vertically <p>(avoid spraying if smoke rises vertically!)</p>
1	1 to 5	Light eir	<ul style="list-style-type: none"> • direction of wind shown by • smoke drift, but no wind vanes
2	6 to 11	Slight breeze	<ul style="list-style-type: none"> • wind felt on face; leaves rustle; • ordinary vane moved by wind
3	12 to 20	Gentle breeze	<ul style="list-style-type: none"> • leaves and small twigs in • constant motion; wind extends • light flag
4	20 to 28	Moderate breeze	<ul style="list-style-type: none"> • raises dust and loose paper; • small branches are moved

Inversions

Do not spray under *inversion* conditions. This is where a blanket of cold air is trapped above the ground and temperatures increase with altitude rather than decrease. Blankets of fog or smoke indicate such conditions as smoke will not rise, but drift at a constant height under the inversion layer.

Temperature and humidity

High temperatures can have a two-fold affect on drift—that of volatilisation and evaporation. Firstly, higher ground temperatures establish air currents which result in spray mists carried high and dispersed over a wide area. Secondly, the high temperatures can evaporate the liquid in the droplets and the particles of pesticide can be carried as a fine dust over long distances. Avoid spraying in temperatures greater than 30°C.

It is preferable to spray under high humidity. This is particularly important when water is the carrier as low humidities are often associated with high temperatures and thus, high rates of evaporation. Avoid spraying when relative humidities drop below 45%. Under inversion conditions, do not spray with high humidity as it extends droplet life and increases herbicide uptake, thus increasing drift hazard.

In general spray when temperatures are less than 32°C and the relative humidity is high, i.e. when the difference between wet and dry bulb temperatures is less than 10°C (see Table A3-3).

Table A3-3. Temperature and humidity levels when spraying should cease

Temperature (°C)	Humidity (%)	
	Aerial	Ground
20	37	23
24	44	32
30	50	38

2.6. Communication

Communicate with neighbours, aerial and commercial operators notifying them of susceptible crops as well as the location of sheds and homes on your property. At the same time, determine the location and nature of these things on neighbouring properties.

When spraying, communicate your plans to neighbours who may be affected and discuss any drift risks with them. UHF radios are a great asset in this regard as most commercial operators use them. Ground supervision of aerial spraying by a responsible person in communication with the pilot is essential. If conditions become unsuitable during the spray operation, tell the operator to stop or drop the flags and walk from the field.

2.6.1. Records

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. Such records can provide good evidence of such operations, should a dispute arise.

Records should include:

- date and time of application;
- chemical used and rate;
- crop-pest and area sprayed;
- weather conditions; and
- equipment and operating conditions.

2.6.2. Mud map for aerial spraying

To help commercial operators sketch a *mud map* of your property showing prominent land marks, homes and other buildings especially, and reference points. Note susceptible crops both on your property and on your neighbours.

3. Responsibilities and the environment

These days it is not wise to integrate the use of farm chemicals into a farm program such as cotton production without giving some thought to what happens to the chemical and the package it came in after application. This implies knowing a little of the degradation and movement pathways of the chemical, its likely impact on local flora and fauna at both micro and macro levels and how to minimise and dispose of the large number of chemical packages brought onto the property each season. Sometimes management priorities do not allow the best 'green' option and a compromise must be struck but at least some thought should be given to minimising off-target impact and thus maximising the chances of sustainable production.

3.1. Susceptibility of native flora to spray drift herbicide damage

During the 1980s there was an increase in accidental damage to native flora along roadsides, in shade clumps and along watercourses. This was primarily associated with the aerial application of herbicides and defoliants.

Damage seems to be seasonally influenced, with greater damage apparent in conditions of vigorous growth. During fruiting or flowering, herbicides appear to have less effect.

A range of products have been implicated, predominantly as a result of droplet/particle drift. Sprayseed® droplets are capable of being carried long distances, producing spectacular spotting on non-target plants. It is generally felt that if a plant can survive fire, it will survive Sprayseed® drift. Translocation in the plant is very limited with this product.

Glyphosate (Roundup®), Tillmaster®, glyphosate dicamba and glyphosate + 2,4-D ester have all caused damage on different occasions.

Table A3-4. Susceptibility of some common native trees to herbicide spray drift

Species	Susceptibility to	
	Glyphosate (Roundup®)	2,4-D (or 2,4-D mixture)
Belah <i>Casuarina cristata</i>	very susceptible	very susceptible
Currajong	tolerant	very susceptible
Poplar box <i>Eucalyptus populnea</i>	tolerant	?
Wilga <i>Geijera parviflora</i>	susceptible	susceptible

The potential for drift damage to susceptible crops and native flora must be given careful consideration in planning application. The relative merits of aerial application versus ground rig must be weighed up. The chemicals to be used must be carefully assessed. Most importantly, landholders and applicators must be totally aware of the prevailing weather conditions and its likely effect on the job.

3.2. Chemical fate processes

When a pesticide is mixed and applied it immediately becomes subject to numerous environmental forces which fall mainly into physical and biochemical divisions.

Physical or 'transfer' influences

These may include the following:

- (a) *Volatilisation:* If the active or parts of the formulation have a high vapour pressure, it will tend to vapourise after deposition and move away from the target area with ambient air movement.
- (b) *Wind:* Reference to Section B1, 1.2 on droplet transmission indicates how significant the relationship between droplet size and wind can be. Many small droplets leads to wind loss away from target.
- (c) *Run-off and erosion:* Significant rainfall events shortly after spraying can lead to residue wash-off target and movement over the surface of the soil along with water flow. Similarly any earth that has been sprayed that is physically moved through erosion will carry residues with it. The amount will be partly dependant on slopes and ground cover.
- (d) *Leaching:* The significance of the 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 electrical attraction (adsorption) represent the worst scenario – e.g. phenoxy herbicides. At the other end of the scale some chemicals with very low solubility like Trifluralin through sheer persistence may survive long enough without breakdown to contaminate ground water. Most do not pose a threat.
- (e) *Groundwater movement:* If this is contaminated it may be part of a system supplying the water needs somewhere else and take with it potential problems.
- (f) *Crop absorption and harvest:* Under some circumstances chemical residues may leave their paddock of use along with the harvested crop.

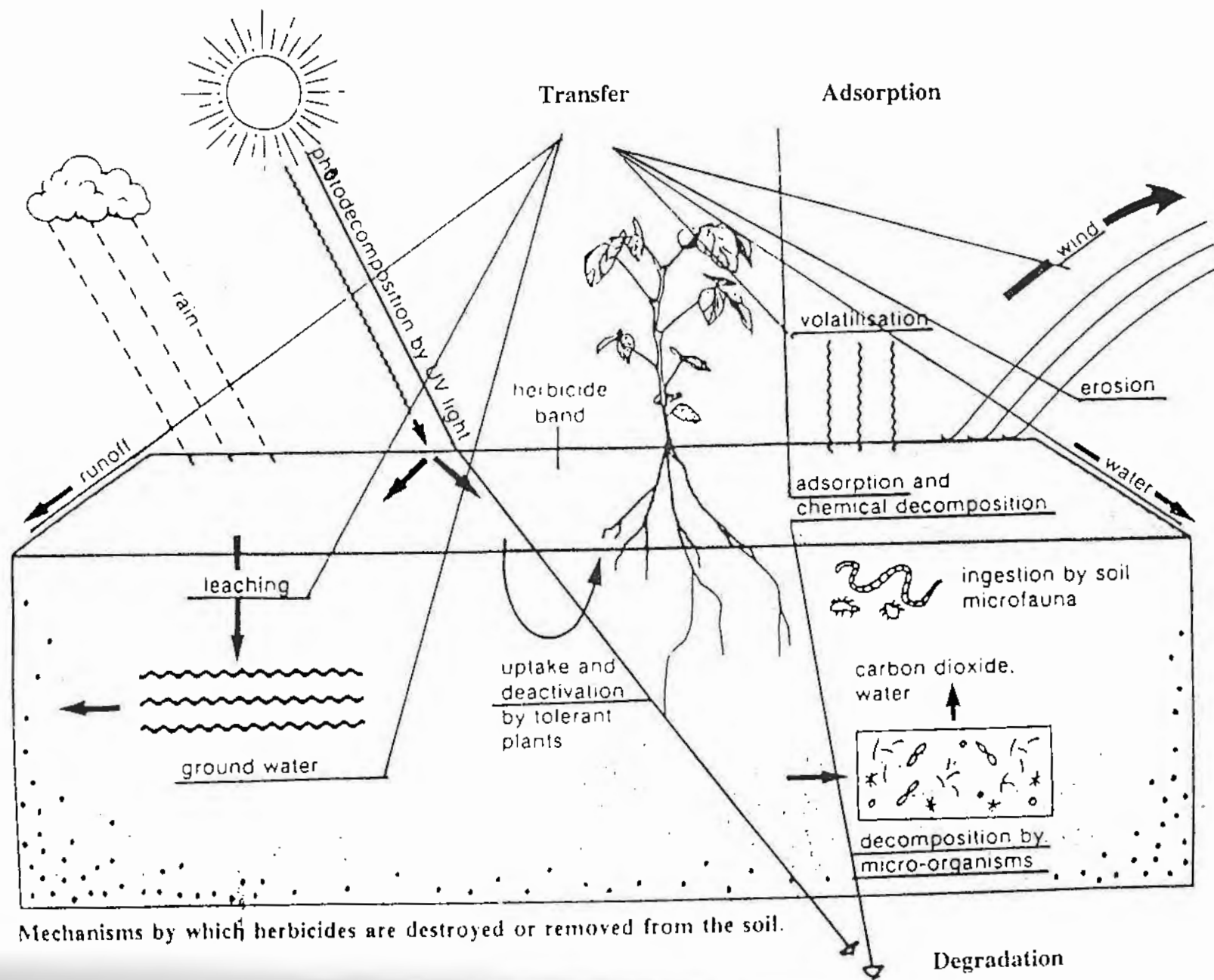
Degradation influences

These breakdown systems result in the actual molecule being modified and possibly totally destroyed with its components of carbon nitrogen phosphorus sulphur oxygen and hydrogen etc being reabsorbed into a myriad of other compounds including things like water, carbon dioxide, chloride salts etc. These reactions are caused in two ways:

- (a) *Chemical:* Again there are two major influences. The first to come into play is ultra-violet radiation as the residue sits on the target exposed to sunlight. This is a powerful force for change and is dependent on the ozone layer for its effectiveness. Chemicals vary quite a lot in their sensitivity to it. The other chemical change is brought about by acid or alkaline soil conditions. Chemicals which are adsorbed to clay and held by electrical attraction can be destabilised insitu by a change in pH. Usually the pH triggers the process known as hydrolysis.
- (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 garner the energy released by its break-up. Another example of bio-degrading is when the crop itself absorbs the chemical and then assimilates it or de-activates it through some enzyme system.

Figure A3-1 illustrates these processes.

Figure A3-1. Degradation Influences



3.4. Disposal and dealing with accidental spills

3.4.1. Used containers or packs

AVCARE Ltd, the National Association for Crop Protection and Animal Health, is in the process of developing a long term strategy for chemical container management.

In essence the objectives are to decrease the number of packages used in the industry by:

- (a) Using bulk and refillable containers.
- (b) Changing formulations where possible (see Section B3) from liquid to solid, crystal or gel.
- (c) Introducing innovative packaging such as water soluble pre-packs in cardboard outers which virtually eliminate plastic disposal problems.
- (d) Recycle containers where practicable or possibly use them as an energy source in furnaces.

Until these trends turn to reality, the cotton grower has a limited number of options for container disposal but before doing this the containers must be thoroughly rinsed. Rinsate can be disposed of by return to a compatible registered spray mix or in a dedicated disposal pit.

Disposal

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

- ⇒ After use, rinse the container three times, adding rinsings 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. See Appendix A3-1 for the AVCARE Ltd recommended rinsing procedures.
- ⇒ Then, pierce or crush the container. Portable drum crushers are available in some areas.
- ⇒ Take crushed containers to an approved tip or bury them (large metal drums may be recycled through approved drum recyclers. The addition of hydrated lime when burying is advisable. See Appendix A3-2.

Further information is available from:

- Australian Cotton Foundation, telephone (02) 319 3677
- AVCARE Ltd, telephone (02) 963 7690
- Your local council

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. Burning containers with residues of volatile herbicides must be avoided. Dispose of plastic containers by burying them, or at an approved tip. It is also preferable to dispose of paper containers in this way.

3.4.2. Establishing a disposal site on a property

Site specifications are:

- (a) Level and above flood height.
- (b) Of a suitable soil type to avoid excess ponding or leaching.
- (c) Clear of water table high point.
- (d) At least 50 m from roadways.
- (e) At least 100 m from water courses.
- (f) Adequately separated from houses, livestock and crops.
- (g) It should be fenced to exclude stock and clearly placarded.

3.5. Dealing with spills

Minor spills of concentrated or diluted pesticide needs prompt action to minimise environmental contamination. The best procedure is:

- (a) First control the cause of the spill if this action is needed (e.g. return a tipped over container to upright).
- (b) Then contain the spill by surrounding it with soil, sand to prevent spread.
- (c) Soak it up with hydrated lime if available as this not only acts as a sponge but actively neutralises any organo-phosphates or carbamates present.
- (d) Collect the material, remove and bury responsibly at a dedicated site.

Major spills in a public place should be handled by the Fire Brigade and after calling them and the Police priority should be given to keeping others away from possible chemical exposure until assistance arrives.

3.6. Efficient strategic use of pesticides

This section has discussed the need for and many aspects of the use of pesticides as a farm management tool. It is obvious their responsible use is quite a complex operation and not necessarily one the grower himself always wants to accept directly. Luckily most cotton growing areas have available contact services both ground and aerial for a number of cotton production operations including spraying. However when the grower wants to do his/her own chemical application the "SPRAY SURE" check list should always be followed.

SPRAY SURE

When spraying pesticides from their own equipment growers should:

- Be sure the equipment is functioning correctly. Check that nozzles are in good condition, use low pressure, wide fan angled nozzles and keep the boom at the minimum height. Use nozzles which reduce the total volume of driftables.
- Be sure pesticides are mixed thoroughly and according to the label.
- Be sure the recommended registered pesticide is used for the job at hand.
- Be sure pesticides are applied at recommended rates.
- Be sure only target plants or weeds are sprayed.

Growers using the services of commercial operators can rely on the operator for these aspects, but it is imperative that he is given full details, preferably with a map, showing:

- compass directions;
- area to be sprayed;
- location of homes, susceptible crops, stock, bee hives, sheds, dams, etc.
- topographic features and hazards; and
- real property description.

4. References

AVCARE Ltd (1989), AVCA Code No. 1, Disposal of farm chemicals and containers on the farm.

Colton, R. T. and Greenup, L. R. 1990, PESTICIDES—your questions answered, NSW Agriculture and Fisheries.

Shaw, A. J., 1994, Cotton Pesticides Guide 1994–95, NSW Agriculture (in press).

McGuffog & Co Pty Ltd, 1994, Operation Clean Rinse Information Bulletin No. 2.

Appendix A3-1

How to properly rinse empty containers

There are several methods of rinsing.

Probes and 'sucker flusher' transfer systems

A number of farmers use chemical concentrate transfer systems that incorporate a flushing operation. 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 types of systems have the added advantage of reducing significantly the potential for exposure of the operator 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 manufacturer's recommendations should be followed. Generally speaking, the rinse cycle should last for at least 30 seconds.

Manual rinsing—pressure rinsing

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 to drain 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 (this is normally at least 30 seconds) or until the rinsate coming from the container is clear. Gyrate 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.

Manual rinsing—triple rinsing

(a three-stage rinsing process)

How to triple-rinse:

1. Remove the cap from the container.
2. Empty the contents into the spray tank and allow the container to drain for an extra 30 seconds after the flow reduces to drops.
3. Fill the container with water to between 20% and 25% of its capacity.
4. Replace the cap securely.
5. Shake, rotate, roll or invert the container vigorously for at least 30 seconds, so that the rinse reaches all inside surfaces.
6. Remove the cap. Add the rinsate from the container into the sprayer tank. Let it drain for an extra 30 seconds after the flow reduces to drops.
7. Repeat steps 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.

Proper management of empty farm chemical containers

- ensures you get 100% value from the chemicals 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.

Appendix A3-2

Read the Label

- The label will indicate protective clothing to be worn and safety directions to be observed when handling the product, and may give information on disposal of containers and unwanted chemicals after use. **STOP, READ THE LABEL, HEED THE LABEL.**

Avoid creating waste.

- Do not buy more than you need.
- Do not mix more than you need for immediate use.
- Take care to avoid spillage during mixing, handling and storage.
- **TRIPLE RINSE** containers after use, and add all rinsings to the tank mix.

Protect Yourself.

- During disposal of waste, wear the protective clothing recommended on the label for use when mixing the product.

Disposal of unwanted farm chemicals.

- Offer unused materials in original, well labelled containers to other farmers who may be in a position to use them.
- Unopened containers may be accepted as a return by your supplier.
- Dispose of unwanted farm chemicals at an approved or licensed site when one is available.
- Where there are no alternative approved disposal sites or facilities, unwanted chemicals, can be disposed of by diluting to 'spray' strength and adding to an on farm disposal pit such as described opposite.
- Used stock dips can also be added to the pit.

Containers

- After use, **TRIPLE RINSE** all containers with water, adding rinsings to the tank mix - **THEN**:
- **HOLE** and **CRUSH** containers
- **TAKE** crushed containers to an approved tip or bury them
- Large metal drums may be recycled through approved drum recyclers

Choice of Site.

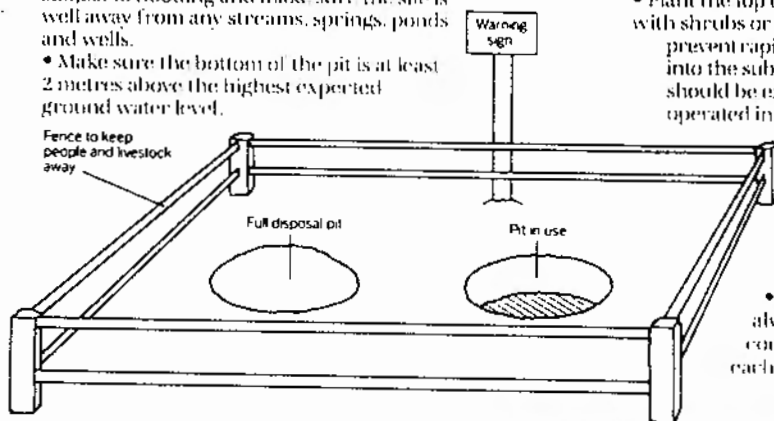
- Disposal should be located away from houses, crop growing areas, stock watering places, dams, irrigation channels, bore and ground water.
- Locate the pit where there is no drainage or seepage into water courses, ground water or sources of drinking water.
- Site should be level.
- Make the burial site deep enough and fence it off to ensure human and animal activities do not uncover waste material. Sign post the site to warn future owners that farm chemical waste has been buried there.
- Avoid excessively sandy sites to prevent leaching into sub-soil water courses. Where a sandy site cannot be avoided, line the pit

with a hole-free piece of heavy duty plastic, such as swimming pool liner. (N.B. A liner should also be used in clay or other areas liable to cracking or movement.)

- Do not choose an area which could be subject to flooding and make sure the site is well away from any streams, springs, ponds and wells.

- Make sure the bottom of the pit is at least 2 metres above the highest expected ground water level.

- When the pit has been filled to a level 50cm from the top, fill with compacted compost or soil and top with a final mound of soil to encourage rain water to run off.
- Plant the top of each filled pit with shrubs or bushes to help prevent rapid drainage of water into the sub-soil. The next pit should be excavated and operated in a similar manner

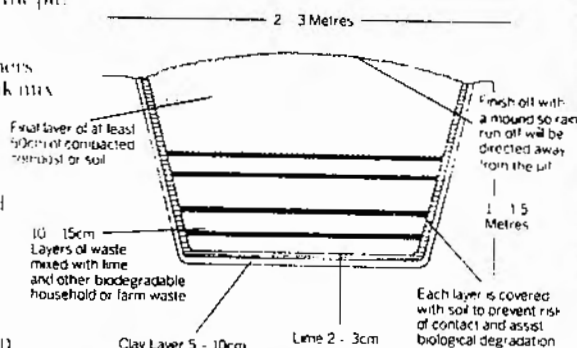


Keep Records

- As an extra precaution always record the composition and date of each waste deposit as you

Construction Details.

- Construct the pit in the form of a bowl with a diameter of 2-3 metres and a depth of 1-1.5 metres.
- Reserve an additional area alongside for a second or third pit for future use.
- Before disposing any wastes, line the pit with 5-10cm of clay and coat it with a further 2-3cm of lime.
- Fence off disposal area to keep people and livestock away from the disposal site. Signpost area to indicate it is a disposal site.



Addition of Waste.

- Add wastes to the pit in layers of not more than 10-15cm depth and intermix them with lime and bio-degradable household waste to assist biological degradation.
- On completion of each deposit, cover the waste with a layer of compost or earth
- Between deposits, cover the pit with a sheet of galvanised iron, heavy duty board of other rigid, waterproof material and weigh down with stones or other heavy objects to prevent entry of rain water.

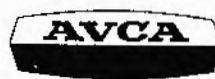
IMPORTANT 'DO'S AND DON'T'S'

- | | |
|--------------|--|
| DO | Read the label |
| DO | Wear protective clothing |
| DO | Keep records of waste disposal |
| DO | Ask for advice from supplier or authorities when you need it |
| DO | Dispose of wastes as and when they are used |
| DO | Comply with local authorities requirements for the disposal of farm chemicals |
| DO | Dispose of wastes at an approved site when possible |
| DON'T | Dispose of products that can be safely used |
| DON'T | Reuse containers or convert drums into feeding troughs or water containers for livestock |
| DON'T | Eat, drink or smoke during disposal work |
| DON'T | Accumulate used containers |
| DON'T | Mix waste chemicals together before disposal |
| DON'T | Allow wastes to discharge into a drain or water course or contaminate groundwater |

Note - State legislation may control disposal of farm chemical wastes.

See AVCACODES for advice:

1. Disposal of Farm Chemicals and Containers on the Farm
2. Farm Storage of Agvet Chemicals
3. Complaints Handling Procedure
4. Disposal of Pesticide Spills
5. STOP - Read the label



The Agricultural Veterinaries Federation of Australia Inc.



NATIONAL FARMERS FEDERATION

This information is issued for guidance only. Individuals must accept responsibility for their own actions. This guide does not replace relevant laws and regulations. (1997)

SECTION B1

**Droplet generation
and behaviour**

Appendix A3-2

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- Unopened containers may be accepted as a return by your supplier.
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- Used stock clips can also be added to the pit.

Containers

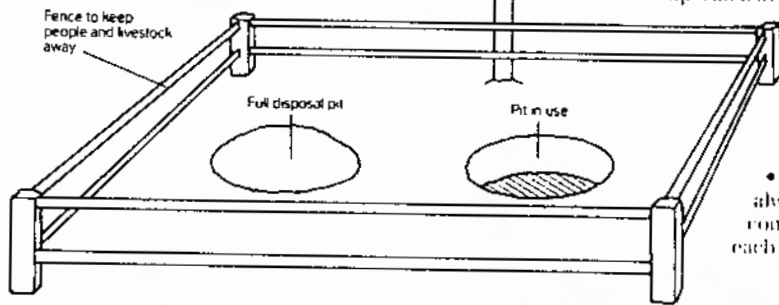
- After use, **TRIPLE RINSE** all containers with water, adding rinsings to the tank mix - **THEN:**
- **HOLE and CRUSH** containers
- **TAKE** crushed containers to an approved tip or bury them
- Large metal drums may be recycled through approved drum recyclers

Choice of Site.

- Disposal should be located away from houses, crop growing areas, stock watering places, dams, irrigation channels, bore and ground water.
- Locate the pit where there is no drainage or seepage into water courses, ground water or sources of drinking water
- Site should be level.
- Make the burial site deep enough and fence it off to ensure human and animal activities do not uncover waste material. Sign post the site to warn future owners that farm chemical waste has been buried there.
- Avoid excessively sandy sites to prevent leaching into sub-soil water courses. Where a sandy site cannot be avoided, line the pit

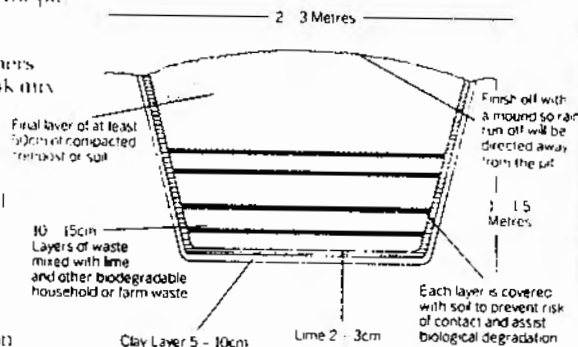
with a hole-free piece of heavy duty plastic, such as swimming pool liner. (N.B. A liner should also be used in clay or other areas liable to cracking or movement.)

- Do not choose an area which could be subject to flooding and make sure the site is well away from any streams, springs, ponds and wells.
- Make sure the bottom of the pit is at least 2 metres above the highest expected ground water level.



Construction Details.

- Construct the pit in the form of a bowl with a diameter of 2-3 metres and a depth of 1-1.5 metres.
- Reserve an additional area alongside for a second or third pit for future use.
- Before disposing any wastes, line the pit with 5-10cm of clay and coat it with a further 2-3cm of lime.
- Fence off disposal area to keep people and livestock away from the disposal site. Signpost area to indicate it is a disposal site.



Addition of Waste.

- Add wastes to the pit in layers of not more than 10-15cm depth and intermix them with lime and bio-degradable household waste to assist biological degradation.
- On completion of each deposit, cover the waste with a layer of compost or earth.
- Between deposits, cover the pit with a sheet of galvanised iron, heavy duty board of other rigid, waterproof material and weigh down with stones or other heavy objects to prevent entry of rain water.

- When the pit has been filled to a level 50cm from the top, fill with compacted compost or soil and top with a final mound of soil to encourage rain water to run off.
- Plant the top of each filled pit with shrubs or bushes to help prevent rapid drainage of water into the sub-soil. The next pit should be excavated and operated in a similar manner.

Keep Records

- As an extra precaution always record the composition and date of each waste deposit as follows:

IMPORTANT 'DO'S AND DON'T'S'

DO	Read the label
DO	Wear protective clothing
DO	Keep records of waste disposal
DO	Ask for advice from supplier or authorities when you need to dispose of wastes, as and when they are available.
DO	Comply with local authorities' requirements for the disposal of farm chemicals
DO	Dispose of wastes at an approved site when possible.
DON'T	Dispose of products that can be safely used
DON'T	Reuse containers or convert drums, feeding troughs or water containers, livestock
DON'T	Get drunk or smoke during disposal
DON'T	Accumulate used containers
DON'T	Mix waste chemicals together before disposal
DON'T	Allow wastes to discharge into a drain, water course or contaminate groundwater

Note - State legislation may control disposal of farm chemical wastes.

See AVCACODES for advice:

1. Disposal of Farm Chemicals and Containers on the Farm
2. Farm Storage of Agrivet Chemicals
3. Complaints Handling Procedure
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The Agricultural & Veterinary Chemicals Council of Australia

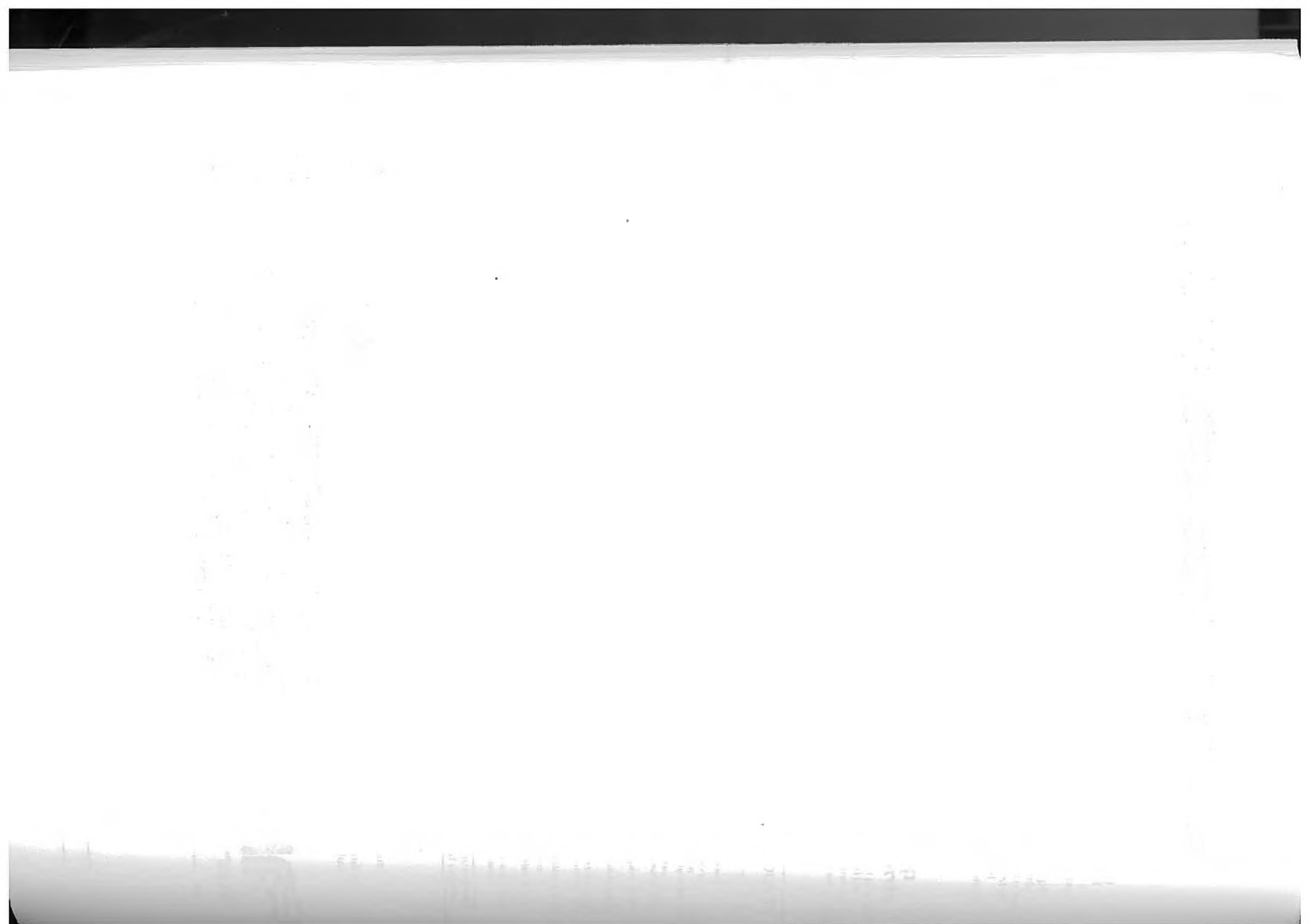


NATIONAL FARMER FEDERATION

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SECTION B1

**Droplet generation
and behaviour**



DROPLET GENERATION AND BEHAVIOUR

Introduction

The farmer faces a difficult problem. How can a small quantity of a biologically active chemical be distributed evenly over a valuable cotton crop 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. Many pesticides in their "natural" state are crystals or viscous liquids, so the formulation chemist and chemical company have the sometimes complex task of manufacturing an appropriate easy to apply liquid, (Section B3).

The most common method of spraying pesticides involves creating a large number of small droplets from a body of liquid which contains the active constituent at the correct concentration for the particular purpose.

Successful spray application involves three main phases:

1. Droplet generation (creating a large number of small droplets from a body of liquid)
2. Droplet transmission (movement of the droplets from the nozzle through the air to the target)
3. Droplet capture (droplets depositing on the target)

1. Droplet generation

(refer also to Section A2)

In order to create a droplet, which carries and transports the active constituent to the target, energy must be expended on the bulk spray solution. This can be done by three alternative methods:

1. By forcing the spray liquid under pressure through a small specially designed orifice. Such devices are normally referred to as hydraulic nozzles and they are available in a number of different types designed for different purposes. The most common types of hydraulic nozzles used for cotton spraying are hollow cone and flat fan nozzles. CP nozzles, a recent introduction to aerial spraying, are also an example of a hydraulic nozzle.
2. By subjecting the liquid to centrifugal energy. By precisely feeding liquid onto a spinning disc it is possible to generate droplets 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 flowrate. Spinning cages as used in "Micronair" units are an extension of this principle. These are normally referred to as controlled droplet applicators (CDA) as they generally produce a narrower range of droplet sizes than hydraulic nozzles.
3. By feeding liquid into a high velocity jet of air, droplets can be generated as the liquid is torn into small particles by the mechanical impact of the moving airstreams. Systems employing this principle are normally referred to as air shear nozzles.

1.1 The birth of droplets

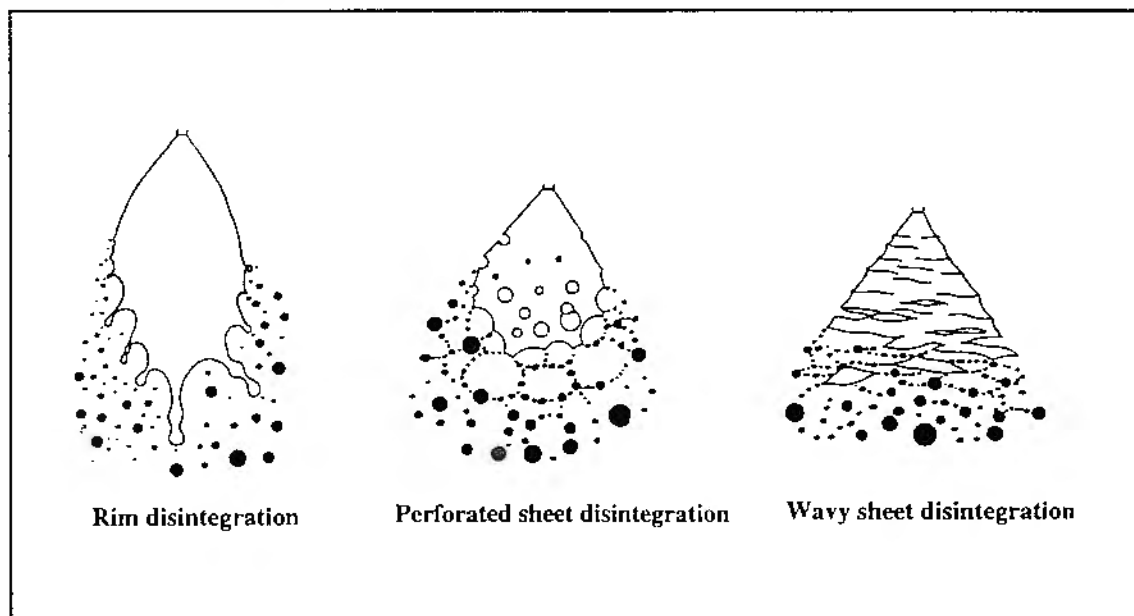
As the forces described above are applied to a spray solution, they induce changes in the physical shape of the liquid. Liquids, whether they be water or oil based do not compress easily so they tend to change shape in reaction to the value and direction of the influence when subjected to a force. There are several characteristic phases of droplet formation.

1. **Sheet formation:** The appearance of sheets of liquid immediately through a hydraulic nozzle or sometimes just beyond the edge of a spinning disc.
2. **Ligament formation:** The formation of ligaments or "strings" of liquid and sometimes liquid cylinders often at the edge of sheets.

In order to form droplets, the sheets and ligaments must disintegrate further and this usually arises 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 B1-1.

Figure B1-1. Rim disintegration, wave disintegration and perforation

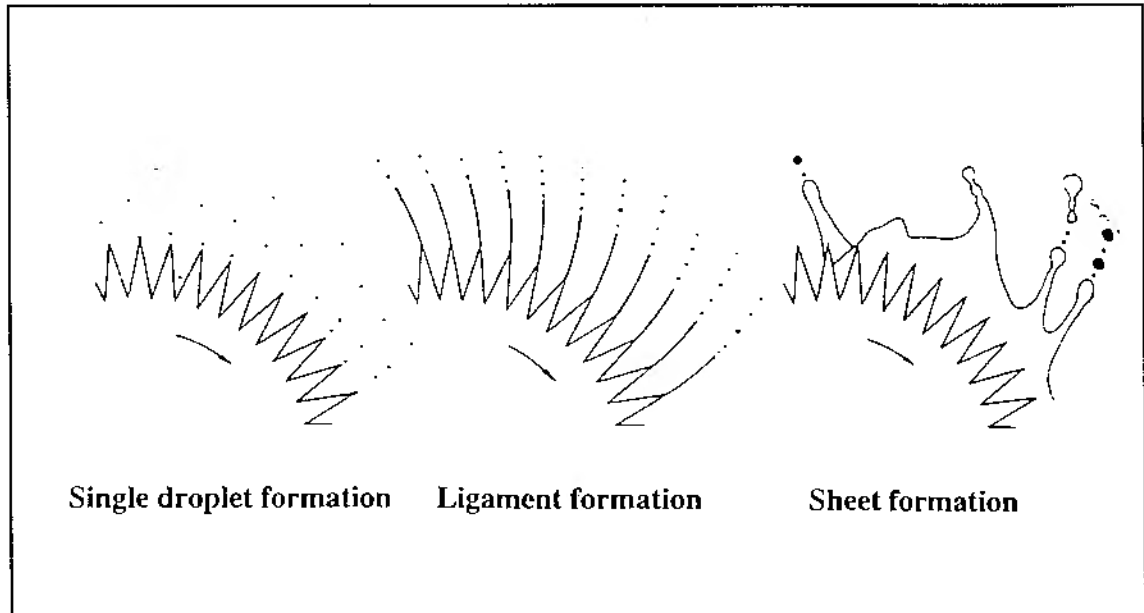
(Source: Pesticide Application Manual 2nd edition, Queensland Department of Primary Industries, Information Services Q189003, 1990—see further reading Section B6)



Rotary nozzles can produce droplets directly from the spinning disc (Figure B1-2). This typically occurs at low flowrates. As flowrate increases ligaments form which then break into droplets. At very high flowrates, flooding of the nozzle may occur producing a sheet of liquid which disintegrates into droplets in the same mode of disintegration as hydraulic nozzles.

Figure B1-2. Droplet formation in rotary nozzles

Source: Pesticide Application Manual 2nd edition, Queensland Department of Primary Industries, Information Services Q189003, 1990



Liquid properties can also influence droplet generation. Increasing the viscosity (thicker liquids) will damp the disturbances resulting in larger droplets being produced. Increasing the surface tension of the liquid will also result in larger droplets being produced.

1.2 Droplet transmission

Once the droplet is generated it must be transferred through the air to the target. The movement of a droplet through the air is influenced by the sprayer type, its initial speed of travel, gravity and prevailing weather conditions.

Gravity causes droplets to fall towards the earth's surface and this is referred to as sedimentation. The speed reached by a droplet when a balance occurs between air resistance to its fall and the pull of gravity is known as its terminal velocity. This varies with the diameter of the droplet, being low for small droplets and significantly higher for large droplets. In the real world this is important as the longer it takes for a droplet to fall to the earth, the more time is available for it to be shifted away from its intended target by cross winds. To complicate matters further, low humidity and high temperatures can cause droplets, particularly water based droplets, to shrink by evaporation and remain exposed to possible sideways movement for even longer time periods.

The following table (Table B1-1) illustrates the theoretical downwind distances droplets will be transported if released 3 metres above a crop in a steady cross wind blowing at 1 metre per second. The effect of evaporation and turbulence is ignored. In practice effects such as turbulence have a major influence on downwind deposition and **Table B1-1 should not be used to predict safe downwind buffer areas.**

Table B1-1. Terminal velocities for different droplet sizes

Droplet Diameter	Terminal Velocity	Time to Fall	Downwind Displacement
(μm)	(m/s)	3 m	in 1 m/s wind (m)
1	0.000 03	28.1 hours	10 000
10	0.003	16.9 min	1000
20	0.012	4.2 min	250
50	0.075	40.5 sec	40
100	0.28	10.9 sec	10.7
200	0.72	4.2 sec	4.2
500	2.14	1.7 sec	1.4
1000	5.0	0.8 sec	0.6

The main weather conditions which influence droplet transmission are temperature, relative humidity, local wind speed and direction. Importantly, droplets are transported in a direction corresponding to the local prevailing wind. Temperature and relative humidity influence the evaporation of the droplets. The importance of meteorological factors in relation to droplet behaviour is discussed in more detail in Section B2.

Initial energy imparted by a nozzle and the use of a high speed air stream or electrostatic charges can also influence the transmission of droplets. However, once this force is removed droplets (particularly small droplets) quickly lose any influence imparted by such forces and fall entirely under the influence of gravity and wind.

1.3 Droplet capture

For the spraying to be effective droplets must be deposited on the target. Target size, shape and orientation, droplet velocity and size and weather conditions all influence the ability of the droplet to land on the target.

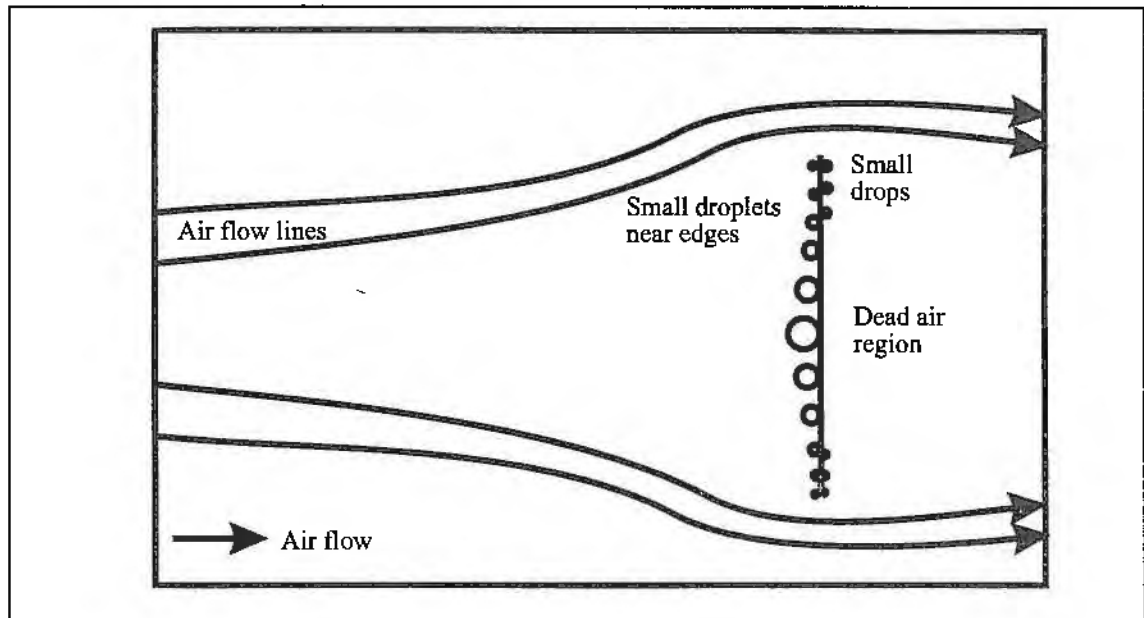
Large droplets will deposit on horizontal surfaces such as the ground surface or broadleaf weeds due to sedimentation. Deposition on vertical surfaces or the lower surface of a leaf is increased by using small droplets which become subject to horizontal wind movement and turbulence.

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. The flow of air around an object is shown in Figure B1-3.

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:

- a) the relative velocity between the droplet and the target increases
- b) the diameter or width of the target decreases
- c) the droplet size increases

Figure B1-3. Air flow around a flat plate



Consequently if small droplets are applied over a crop the catching efficiency of the canopy would increase if wind speeds were elevated and crop profile consisted of numerous small branches and hairy surfaces. Note that the use of elevated winds can increase the drift potential of a spray.

Most natural surfaces are not smooth. Plants may have a complex rough surface comprising of small protruding spikes or hairs and leaf veins. All these factors help to increase the catch efficiency of the plant. Movement of the leaves due to air flow also increases the catch efficiency.

Not all droplets which 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 so much kinetic energy that they can shatter on impact. Droplet retention is therefore a function of pesticide formulation, (surface tension), droplet size and leaf morphology. The grower should note that where a surfactant (wetter) is recommended to reduce surface tension and increase retention, the addition of too much agent can excessively decrease the surface tension and cause droplets to run off leaf surfaces.

1.4. Droplet size

Droplets used in spraying agricultural crops are small! We glibly refer to droplets of 10, 100, or 500 μm forgetting that 10 and even 100 μm droplets may not be visible to the naked eye (refer Figure A2-1). As an example the full stop at the end of this sentence is approximately 400 μm diameter. It would be considered a large droplet in spray application technology. A micrometre (= micron- μm) is 1/1000 of a millimetre (mm) and thus a 500 μm droplet is half a mm in diameter.

Unfortunately no practical spray nozzle produces droplets which are all the same size. All commercial nozzles generate a range of droplet sizes. A summary of the main values which are used to describe the droplet spectra produced by different nozzles is presented in Table B1-2. The 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 smaller than the VMD. Two different nozzles may produce the same VMD but may actually produce a quite different droplet spectra. One nozzle may produce droplets which all fall in a very narrow band around the VMD while the other nozzle may produce a very large range of droplet sizes. Similarly the Number Median Diameter (NMD) divides the droplet sample in half by number. The NMD is always less than the VMD.

A diagrammatic representation of VMD and NMD is shown in the following figures:

Figure B1-4. Illustration of the Volume Median Diameter (VMD)

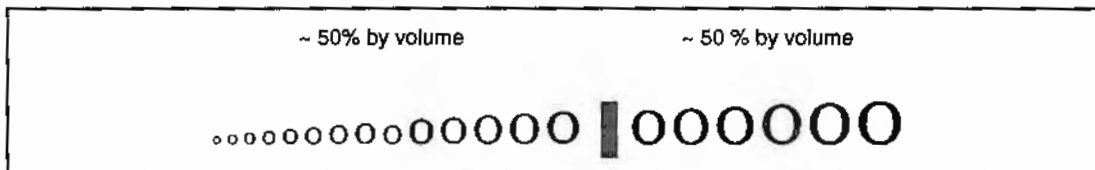
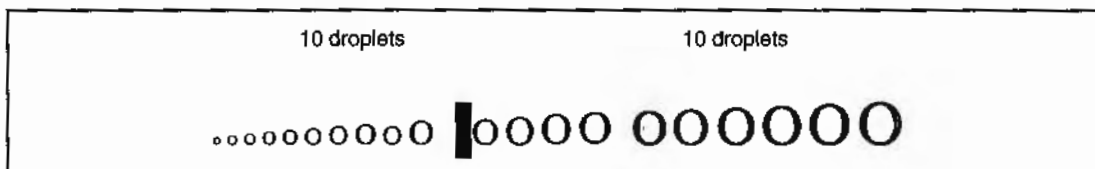


Figure B1-5. Illustration of the Number Median Diameter (NMD)



Droplet spectra can also be represented graphically by a frequency distribution or histogram (Figure B1-6). The frequency distribution indicates the range of droplet sizes produced by a nozzle from which the VMD can be calculated. Figure B1-6 shows the droplet size distribution for a flat fan hydraulic nozzle determined in the laboratory by the Centre for Pesticide Application & Safety. The spray spectrum had a VMD of 255 μm . Note the large range of droplet sizes generated from about 15 μm to 1500 μm .

Figure B1-6. Hydraulic Nozzle (Flat Fan) Droplet Frequency Distribution

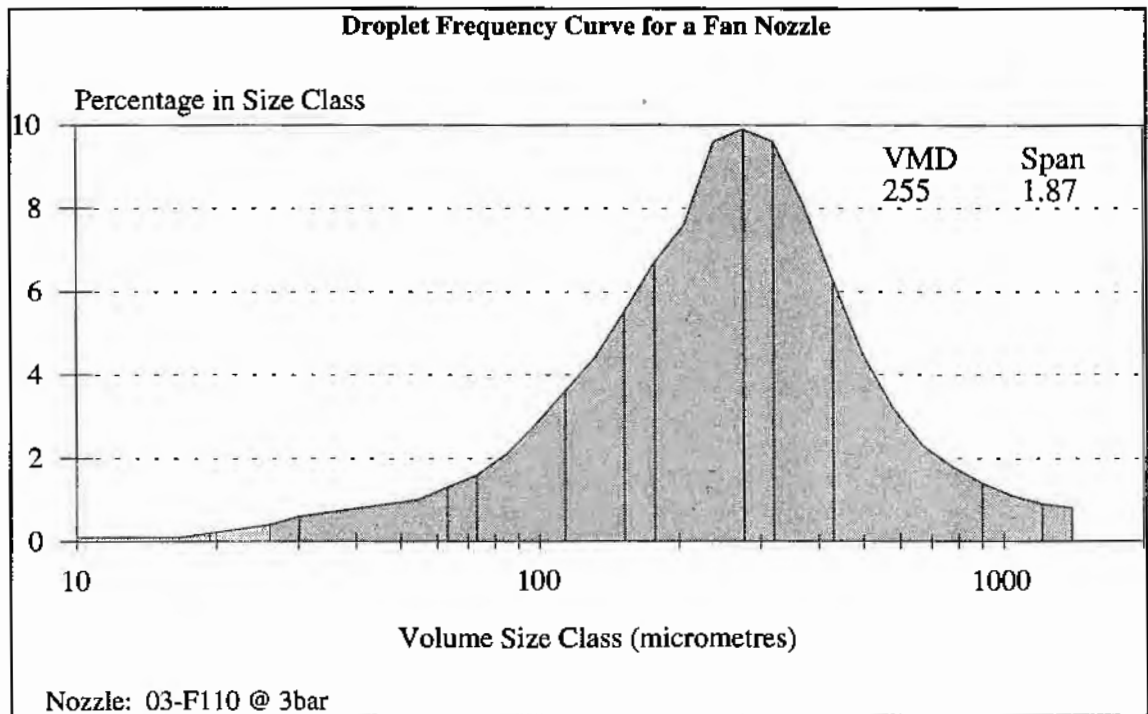


Table B1-2. Summary of some technical definitions used for describing droplet size

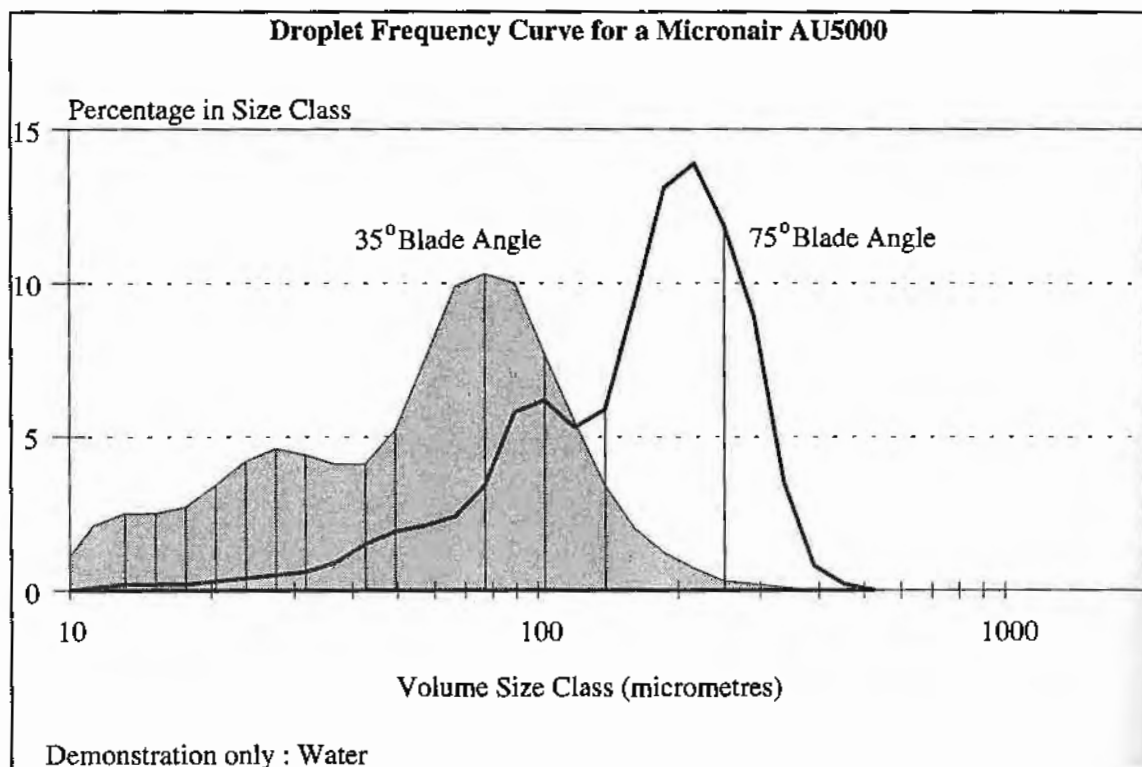
	Definition	Units	Comments
VMD or D[v,0.5]	Volume Median Diameter Diameter that contains 50% of volume in drops of smaller size.	(μm)*	<ul style="list-style-type: none"> Most commonly used value for describing droplet size.
D[v,0.1]	Diameter that contains 10% of volume in drops of smaller size.	(μm)	<ul style="list-style-type: none"> Useful indication of small droplets which are prone to drift.
D[v,0.9]	Diameter that contains 90% of volume in drops of smaller size.	(μm)	<ul style="list-style-type: none"> Useful indication of large droplets which can be wasteful of chemical.
Relative Span	Measure of the width of the volume distribution relative to the median diameter VMD $= \frac{D[v,0.9] - D[v,0.1]}{\text{VMD}}$	**	<ul style="list-style-type: none"> The lower the span the more uniform the droplet spectra. For monosized droplets span = 0
NMD	Number Median Diameter Diameter that contains 50% of number in drops of smaller size.	(μm)	<ul style="list-style-type: none"> NMD is always less than VMD except for monosized droplets where NMD = VMD
R	Measure of the width of the volume distribution $= \text{VMD}/\text{NMD}$	**	<ul style="list-style-type: none"> The smaller the value of R the more uniform the droplet spectra. For monosized droplets R = 1

* micrometre or microns = 1/1000 mm

** dimensionless

As an example of a droplet spectrum from a centrifugal energy nozzle, Figure B1-7 shows a typical frequency distribution of a Micronair AU5000 using a blade angle of 35 and 75 degrees. Note the larger VMD (178 μm) obtained using a 75 degree blade angle and thus a slower cage velocity than the 35 degree blade angle (63 μm VMD).

Figure B1-7. Micronair AU5000 Droplet Frequency Distribution 35 and 75 degrees



1.5. Droplet size measurement and recovery

Different spray operations such as the application of insecticide or herbicide require different drop sizes in order to produce a result which is both efficient and environmentally sound. Nozzle spectra produced by various nozzles are categorized into groups based on droplet size (VMD), i.e. coarse, medium and fine (the VMD ranges for these categories are defined in Table A2-1). Apart from nozzle type, differences between commercial pesticide formulations can also significantly influence the droplet size generated by a particular nozzle. For example as shown above, the Micronair AU5000 commonly fitted to aircraft can be set up to produce small droplets suitable for insecticide, ULV (Ultra Low Volume) spraying as well as medium sizes droplets suitable, for example, for insecticide EC spraying, simply by altering its driving blade angle. Significant changes in the droplet spectra can also occur using a common blade angle setting when used with two different formulations. To optimise deposition on the biological target during spray operations, it is important to know the droplet spectra generated by different formulations and nozzle types.

Most methods of droplet sizing and pesticide recovery remain the domain of application scientists given the cost and complexity of modern analytical equipment. For the interest of the grower some of the more complex procedures are briefly described below. However estimates of droplet recovery and approximate droplet size can be made using products such as water and oil sensitive paper.

1.6 Water and oil sensitive paper

Water sensitive paper (WSP) consists of a specifically manufactured card which has a yellow surface on one side specially coated so that when water based droplets impinge on 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 by means of droplet deposition (droplets/cm²) 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 50µm do not stain the card if the relative humidity is less than 50% and under very humid conditions the paper turns blue.

Such products are best used when cut into small strips and stapled to the cotton canopy. Estimates of droplet recovery can be made by determining the average droplet numbers deposited per unit area on the cards over a significant sampling area. As a **rough guide** droplet numbers on the upper canopy should ideally exceed 20 droplets per sq. cm for most types of application (refer Figure A2-1). Where accurate determination of droplet numbers and the percentage area covered is required cards can be sent to the Centre for Pesticide Application & Safety for computer based image analysis. Water and oil sensitive paper can be purchased in Australia from Sprayflo Pty Ltd, telephone (03) 818 1255, fax (03) 819 1022 or Queensland, telephone (07) 232 0460.

1.7. Advanced analytical techniques

This section briefly discusses some advanced techniques employed by scientists to determine droplet size and pesticide recovery in the field and laboratory.

Droplet sizing can be performed by a variety of fully automated, semi-automated or manual methods. Techniques such as laser diffraction measure the droplet spectra of a cloud of droplets in flight near the point of emission from the nozzle. 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.

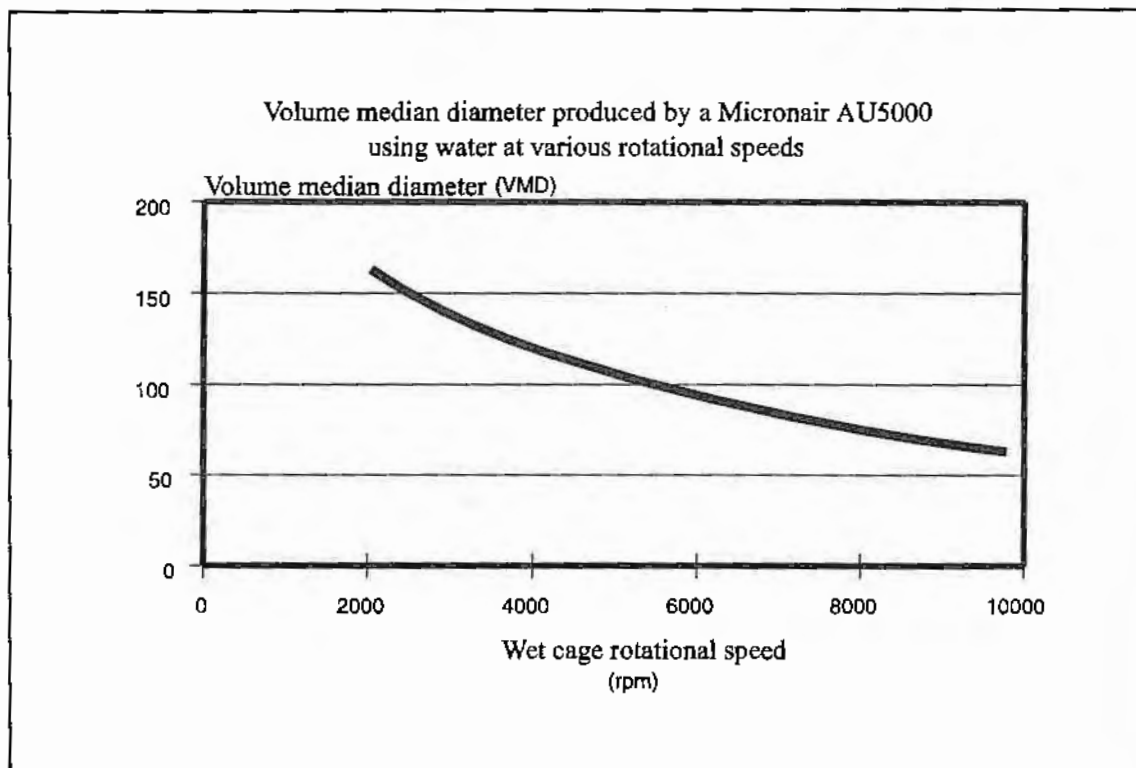
Other methods of droplet measurement require the capture of droplets on or in a suitable medium so that droplets are made visible for sizing. Numerous types of media have been used to capture droplets, some of which include, coated slides (a thin layer of magnesium oxide, an impression is left when droplets impact), coated film, glossy paper (i.e. kromekote card), sensitive papers (i.e. water and oils sensitive paper), leaf surfaces, collection in liquid media and fibrous media. Droplet stains on cards and leaves can be made visible by adding a visible or fluorescent dye to the spray mix or alternatively using a surface that changes colour upon droplet impaction such as water sensitive paper. When visible, droplets can be sized using computer based technology such as image analysis or performed manually, using a calibrated eye-piece hand lens or microscope. In order to obtain a satisfactory estimate of the VMD, large numbers, usually greater than 1000 individual drops must be sized. A correction must be applied when sizing drops on an artificial or natural surface to account for the 'spread factor'. That is, the droplet stain may appear larger on the surface than the true drop size in flight. The spread factor will vary depending on formulation, drop size and the type of collection surface.

As a spray cloud consists of a range of droplet sizes care is required when sampling the cloud, to ensure a representative sample of drop sizes is collected on an artificial surface. The effect of drop size, target size and droplet velocity on the collection efficiency have been discussed in a previous section.

1.8. Laser techniques

Laser based techniques such as that of the Malvern 2600 and PMS (Particle Measuring Systems Inc.) are unobtrusive and provide a rapid method for assessing the effect of pesticide formulation or nozzle type on droplet spectra. These methods are limited in that the droplet cloud passing through the laser must be sufficiently dense to provide accurate estimation of a droplet spectrum, hence the spectra may only be determined if the laser is near the point of generation. The type of data obtained using a Malvern 2600 is presented graphically in Figure B1-8. This figure shows the VMD, generated for a Micronair AU5000 over a range of wet cage speeds with water.

Figure B1-8. Droplet spectra of a Micronair nozzle as measured by a Malvern 2600



1.9. Fluorometric analysis

Fluorometry provides a relatively low cost method for obtaining quantitative data on the spray volume recovered in the field. The technique is based upon adding a fluorescent dye to the pesticide before application. The dye is extracted from artificial collectors or leaf samples using a solvent. A calibrated fluorometer is used to quantify the dye present in the solvent used for extraction. Readings obtained from the fluorometer, in most cases are directly proportional to the level of active ingredient in the pesticide formulation. Fluorometry is a useful analysis method applicable to field studies where it is required to determine the distribution and penetration of pesticides into a crop canopy or calculating the optimum swath width for ULV spraying based on the deposit levels obtained directly in the crop.

1.10. Image analysis

Digital image analysis provides a semi-automated means for analysing pesticide deposits on both artificial and natural surfaces. Image analysis can be used to provide detailed data on pesticide deposits such as droplet densities, percent area cover and droplet size determination. Images of spray deposit can be obtained on computer with the use of a camera and analysed providing there is good contrast between the spray deposit and the background of the collection media. Leaf surfaces can be analysed with this technique, providing a visible or fluorescent tracer is added to the spray mix. Due to variation in leaf colour and surface terrain between different crop plants, obtaining a high contrast image can sometimes be difficult to achieve.

These techniques are available to the industry through the Centre for Pesticide Application and Safety.

For further information contact C-PAS, telephone (074) 601 293, fax (074) 601 283.



SECTION B2

**Meteorology
and spraying**



METEOROLOGY AND SPRAYING

Introduction

In previous sections the importance of identifying the correct target and choosing the most appropriate chemical have been discussed. As has been demonstrated in Section B1 technology now exists for scientists to accurately determine droplet size spectra as a function of nozzle type and formulation. The cotton grower can now have access to droplet size data generated by selected hydraulic nozzles and aircraft Micronair equipment. However, once formed and released by a sprayer or aircraft the droplets have to be transferred to the target in flight through the air. It is at this stage that the atmosphere has an important influence on the behaviour of the droplets and consequently their final resting place and efficacy in the crop. Most growers are familiar with the effects of local weather conditions on the growth cycle, plant damage, and harvesting etc. In this section the practical influence of four main meteorological parameters on spraying will be highlighted.

1. Horizontal wind speed and direction

Figures B2-1 and B2-2 show infrared photographs taken by satellite 36500 km above the surface of the earth. Cool areas such as clouds show up white whereas warm (sea and land) regions return a dark image on the infrared print. Differential heating of the ground and sea by solar energy 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 is of prime importance to the spray applicator. Not only does the wind largely control the direction of spray after release from a sprayer (and thus its movement towards or away from the target area), but also the degree to which droplets are caught by the foliage or pest and the uniformity of deposit.

Figure B2-1. Copy of infrared photograph taken by satellite

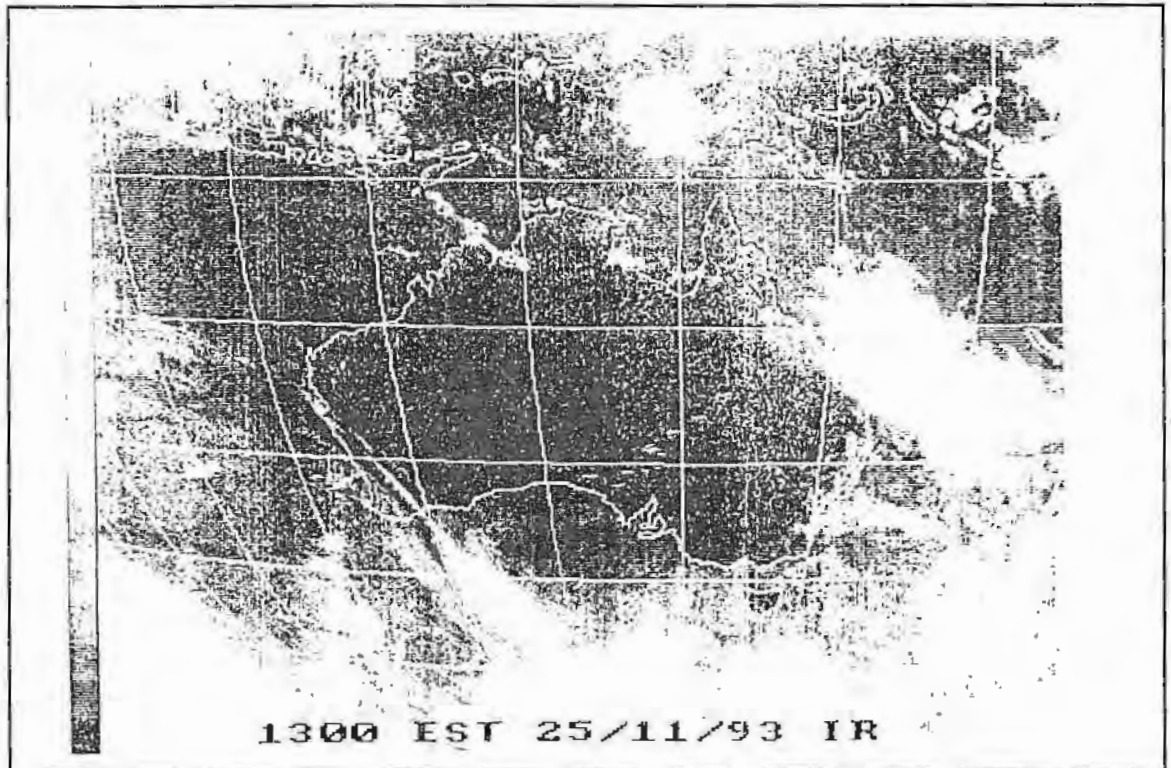
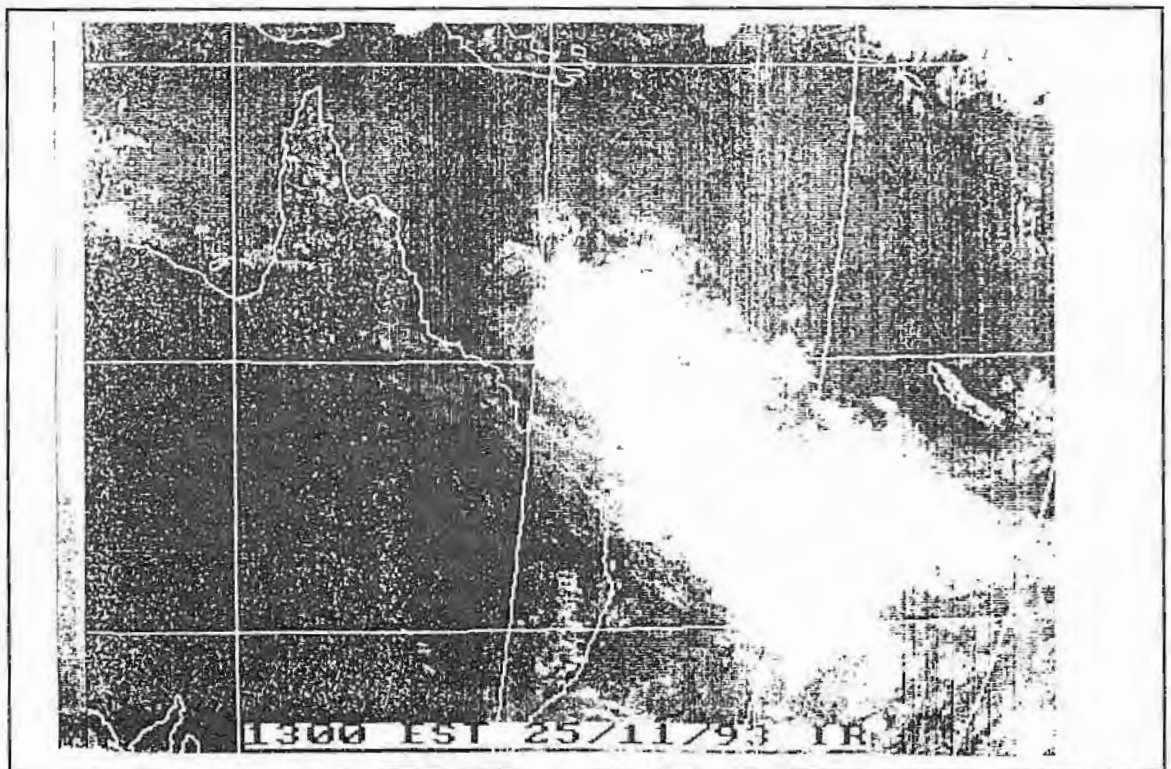


Figure B2-2. Copy of infrared photograph taken by satellite

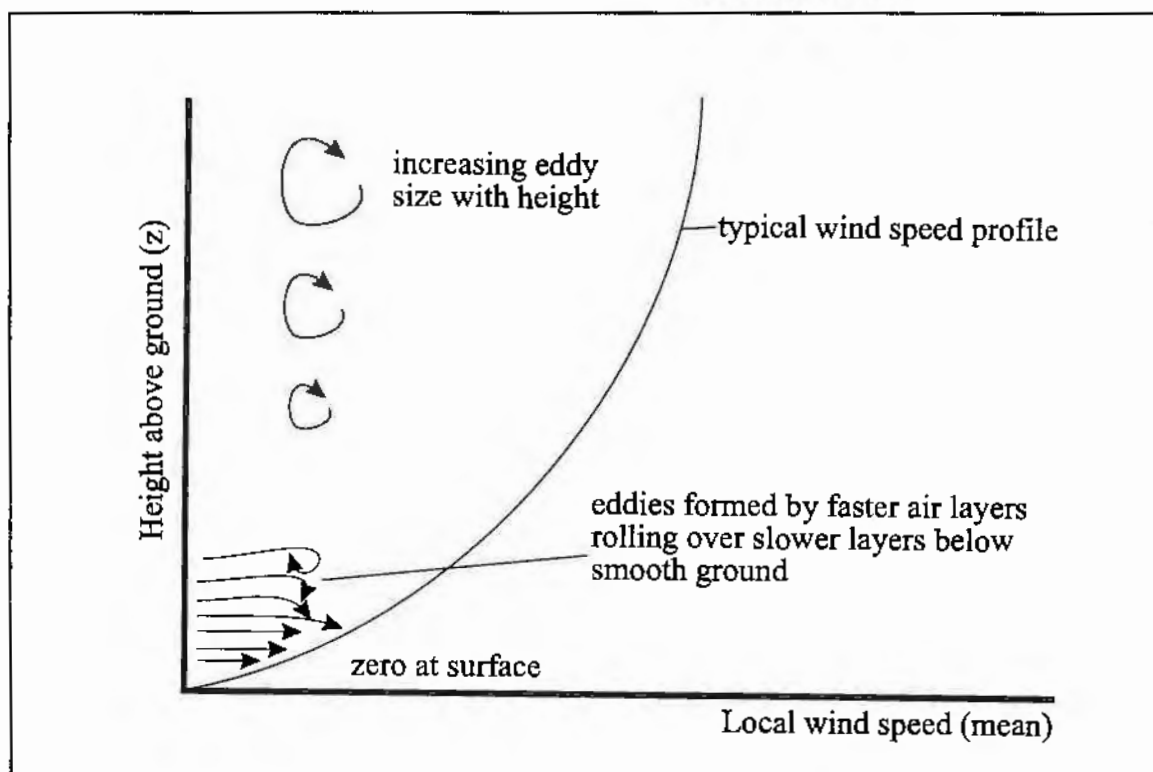


1.1. Turbulence

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. Instead 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. This effect is shown diagrammatically in Figure B2-3. The lower air layers move slower than the upper layers because their energy is lost at the earth's surface. The Figure also shows that close to the earth's surface mean wind speed usually increases with height.

The extent of this turbulence is also determined by the 'roughness' of the surface. For example, a stand of trees or tall crop would generate greater turbulence, for a given wind speed than an area of mown grass.

Figure B2-3. Wind gradient and generation of rotational eddies



1.2. 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 can be formed with resulting wind flows and turbulence.

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:* Common in all cotton growing areas 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 more dense and thus heavier than surrounding air. If cooling occurs on sloping ground, heavy air can flow under gravity to lower levels resulting in the generation of local wind flows.

The wind speed can be easily measured by the grower. Reasonably inexpensive hand held vane and cup anemometers can be easily purchased and kept in the 'glove box' of the truck for use prior to spray operations.

2. Vertical air movement (stability)

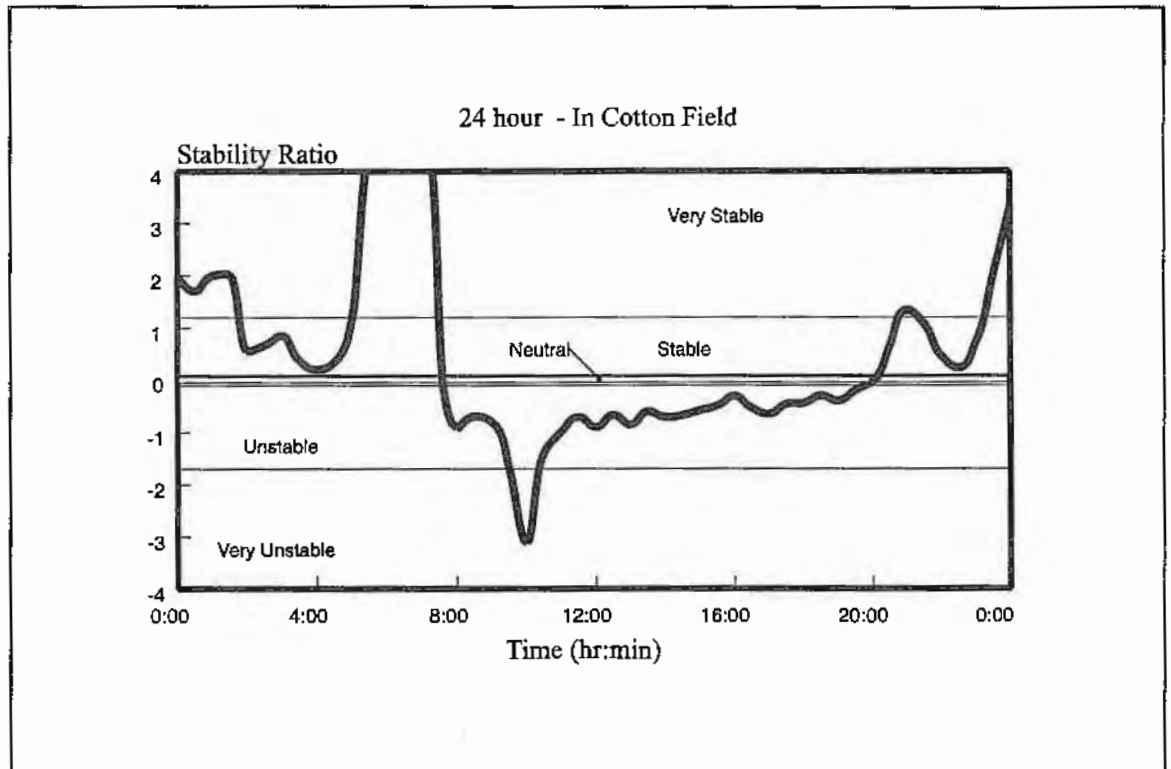
As well as horizontal air movement, the vertical displacement of air has to be taken into account whilst spraying. In fact it can be argued that this parameter is one of the most important factors influencing pesticide application. The atmosphere is a three dimensional space in which air and thus droplets can be transported vertically as well as horizontally.

A parcel of air displaced upwards from the ground (e.g. by convective thermal effects) will normally move into a region of lower pressure and thus 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 normal summer conditions during the late morning and afternoon, air parcels generated in this way tend to rise and remain hot and thus lighter than the surrounding air. The air is said to be unstable and is characterised, should there be sufficient moisture in the atmosphere, by the formation of large cumulus clouds. Air made to rise under such conditions has a tendency to continue its upward motion. Usually thunderstorms develop in strongly unstable atmospheric conditions.

Conversely the atmosphere can be said to be stable. Under such conditions a parcel of air is cooler and thus more dense than the surrounding and tends to return to its original position before displacement. Vertical air movement tends to be suppressed and wind velocities are usually low. A stable atmosphere can occur on dry cloudless nights when the land cools as long wave radiation (heat energy) is emitted by the ground. The ground then cools the air above it and a surface temperature inversion occurs. Under these conditions the temperature increases with height for a finite distance instead of the normal lapse conditions.

Figure B2-4 shows temperature and wind speed data taken above a cotton paddock over a 24 hr period to determine the stability of the atmosphere. The stability is indicated by the stability ratio (SR), a number derived by calculating the temperature gradient above a crop using a tall mast and sensitive thermometers. The graph shows clearly that stability varies considerably according to the time of day. Positive values (stable conditions) in this case were recorded after sunset and before sunrise whereas negative values (increasing instability) were measured during the afternoon after midday.

Figure B2-4. 24 hour stability ratio: Cotton field, 9 January 1993



2.1. Air movement and spraying

This preceding explanation of vertical and horizontal air movement around cotton paddocks can be used to understand the droplet transport process. When droplets are large (say $> 400 \mu\text{m}$) their passage towards the ground from a sprayer is largely influenced by gravitational forces, in other words, droplets will impact on the ground largely unaffected by air currents, unless the wind velocities are very large, (see Section B1, 1.2). However most droplets produced by aircraft, boom sprayers and air assisted sprayers used in cotton are smaller than $400 \mu\text{m}$. As droplets decrease in size, their movement becomes increasingly controlled by the movement of air around them.

Consequently it is important to understand the way in which air is moving above a crop in order to spray effectively and control the off target movement of material which is called 'drift'.

3. Temperature

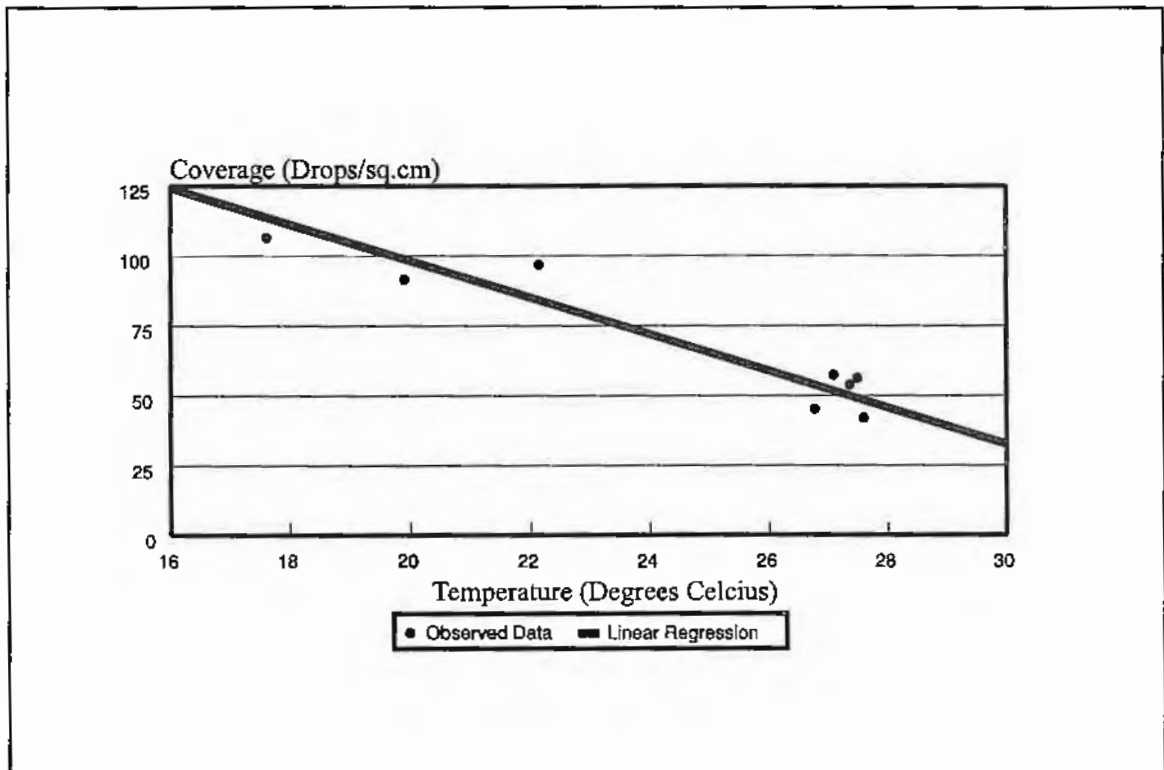
When water based droplets are released into the air by a sprayer they will tend to become smaller as molecules leave their surface and seek to saturate the air space around them. Unfortunately water which is the most commonly used spray carrier is volatile at normal working temperatures and therefore significant reductions in droplet size can occur after droplets have left the nozzle.

The problem is particularly acute for small droplets for the following reasons.

- (a) The 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. It can be shown that this ratio doubles for every halving of the droplet size. In other words, a greater proportion of the volume of the droplet is exposed to the atmosphere as the droplet size decreases.
- (b) As a droplet becomes smaller through evaporation its sedimentation velocity, or rate of fall towards the ground becomes slower, (see Section B1, 1.2). Hence a droplet remains airborne longer and thus more susceptible to further evaporation as it becomes smaller.
- (c) The rate of evaporation of a droplet is related to its size. Experiments have shown that water droplets smaller than about 150 μm evaporate about 27% faster than droplets above this size. This is due to a change in airflow which occurs about droplets smaller than this size. Above 150 μm the airflow is separated from the base of a droplet and no evaporation occurs from this region. By contrast, the flow is attached everywhere on droplets less than about 150 μm and evaporation occurs from the whole surface.

Attempts have been made to calculate the lifetime of droplets and thus the theoretical distance they will fall under the influence of gravity before all the water has evaporated. Such work 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. 32°C, 10°C (Δ) T, (wet bulb depression, see below)) calculations show that droplets 100 μm in diameter will survive less than 12 seconds and 50 μm droplets less than 3 seconds! Figure B2-5 shows the number of droplets (per cm^2) of a water based insecticide formulation deposited on the upper surface of a cotton canopy at different temperatures during a field trial. The graph shows that less droplets were recovered at the higher temperatures.

Figure B2-5. Deposition of insecticide in top cotton canopy, aerial applications of insecticide applied by air in water



It is clear from the above discussion that water, the principle material used to dilute pesticides, as with some organic solvents used in emulsifiable concentrates, is volatile and that extreme care must be taken when applying small droplets in most Australian cotton growing areas. Many of the insecticides applied using aircraft are formulated in solvents which 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 vegetable oil carriers.

4. Relative humidity

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 which could be contained in the same volume of air if saturated at that temperature. Because it is a relative measure dependent upon temperature, the RH increases as the temperature drops and decreases with increasing temperature. It is usual to find therefore that over a cotton canopy, maximum RH values are recorded at dawn.

The relative humidity and Delta (Δ)T are easily measured in the field using a whirling psychrometer—another instrument for the glove box! Consisting typically of two thermometers mounted on a small frame, the unit is rotated by hand in the shade for a few minutes until stable temperature readings are obtained. The bulb of one of the thermometers is covered with a moist wick which dries in the air and lowers the temperature of the bulb. The drier the atmosphere the greater the amount of evaporative cooling and difference between the two bulb temperatures (wet bulb depression or Δ T). Using suitable tables or calculators it is possible to calculate the relative humidity of the air from these two temperatures.

For further introduction to weather systems and an understanding of weather maps (synoptic charts) a recent pamphlet 'The Weather Map' published by the Bureau of Meteorology is included at the end of this section.

5. The influence of weather conditions on spraying

From the above discussion it follows that the grower should base his decision to spray in part on weather conditions. The following guidelines are set out to assist the decision making process.

1. Be capable of determining existing weather conditions and judging the likely changes in the weather. Recently the Bureau of Meteorology and Telecom launched the INFOFAX system. Any person able to have access to a facsimile machine can call an '019' number or dial a special STD Melbourne number and receive latest satellite infra red photographs of Australia, synoptic charts and forecasts. Such information is useful for determining likely synoptic wind directions and temperatures. For more information contact the Bureau of Meteorology in your state capital or fax (019) 725 001. An example of INFOFAX is included at the end of this section.

For approximately \$300 it is possible to purchase a digital vane anemometer and whirling psychrometer. These instruments can be used to determine wind speed temperature and relative humidity respectively. Growers can assist aerial operators and their own decision making process by becoming familiar with basic meteorological parameter measurement.

2. Spraying should only be undertaken when the direction and strength of the airflow is assured. The grower should be satisfied droplets will be carried away from all susceptible areas.
3. Spraying under calm conditions can be hazardous and should only be undertaken with the greatest of care. If the wind strength and direction are unknown, the fate of a product cannot be determined with confidence.
4. Spraying under light and variable wind conditions should be treated with caution. A wind on the change or swinging wildly can lead to striping and the uncontrolled off target deposition of pesticide.
5. The marking of a field with 'smoke' is suggested before the application of agricultural chemicals in sensitive areas or before the application of herbicides. This procedure is also useful for helping to identify the presence of an inversion layer.



BUREAU OF METEOROLOGY

DEPARTMENT OF THE ARTS, SPORT, THE ENVIRONMENT AND TERRITORIES

The Weather Map

The weather map is one of the most familiar images in the community. The best known map is the mean sea level analysis, compiled from hundreds of weather observations (synoptic data) taken simultaneously around the Australian region. It is seen daily on television and in the newspapers.

Its dominant features are the smooth, curving patterns of sea level isobars — lines of equal atmospheric pressure — which show the central elements of our weather systems: highs, lows (including tropical cyclones) and cold fronts. It incorporates the effects of atmospheric processes at higher levels.

Television and newspapers also often carry forecast weather maps which indicate how the weather patterns are expected to develop.

Meteorologists use a wide range of information and techniques to formulate weather forecasts. The weather map does not and cannot show all of these factors. It is a fairly simple representation of past and probable future locations of surface weather systems (highs, lows, fronts, etc.). Nevertheless it provides a useful guide to the weather.

Everyone benefits from a better understanding of the weather map, especially people whose activities are particularly weather-sensitive — pilots, farmers, mariners, builders, outdoor sports enthusiasts — who often find the maps valuable, sometimes essential, to enhance their understanding of media forecasts and help form their own ideas based on local experience.

Preparing the weather map

Specialist observers gather **upper air** information on wind speed and direction by radar-tracking weather balloons, which may also carry instrument packages to transmit temperature and dew-point information at various heights (pressures) in the atmosphere. Some aircraft transmit upper air data.

Weather satellite data are a vital part of the analysis process. Australian meteorologists focus on hourly images from the Japanese Geostationary Meteorological Satellite operating in geostationary orbit 36,500 kilometres over the equator. Computer enhancement adds colour for easier interpretation. The animated sequences often shown on television are a particularly powerful analysis tool.

The Bureau's National Meteorological Centre in Melbourne also draws on similarly enhanced images from US and European geostationary satellites, as well as high-resolution images and atmospheric temperature profiles from polar-orbiting US satellites.

Vast numbers of observations on national and global scale flow to the supercomputers at the Bureau's Melbourne headquarters. The computers' mathematical models (equations) simulate atmospheric processes to produce three-dimensional broadscale weather analyses and prognostic maps which form the basis of weather forecasts for up to four days ahead. The models simulate the physical processes that determine how the atmosphere reacts to constantly changing pressure, temperature and humidity.

Fine-scale surface weather maps are prepared manually in Bureau forecasting offices, particularly the Regional Forecasting Centres in each State capital and Darwin, and Meteorological Offices in Canberra and Townsville.

Meteorologists take account of the centrally produced computer surface and upper air predictions, local data and manual charts, and animated satellite and radar images when preparing forecasts and warnings.

What do weather maps show

The most obvious features of the media's weather maps (Figure 1 is an example) are the patterns of high and low pressure, and the barbed lines identifying cold fronts. In the southern hemisphere, the earth's rotation causes air to flow clockwise around low pressure systems and anticlockwise around high pressure systems. (The opposite applies in the northern hemisphere.) Friction over the earth's surface causes the winds to be deflected slightly inwards towards low pressure centres, and slightly outwards from high pressure systems. Wind strength is directly proportional to the distance between isobars — the closer the lines, the stronger the winds. This rule does not apply in the tropics where the effect of

the earth's rotation is weak. For this reason, tropical meteorologists usually replace isobars

with streamline arrows which indicate direction without directly relating to pressure gradient. Shaded areas on weather maps show where there has been rain in the previous 24 hours, and wind direction is shown with arrows and a series of barbs on their tails to indicate speed.

The coverage on media weather charts is usually limited to the continent and surrounding oceans. The Bureau produces global charts to account of weather systems interacting with each other over great distances. Global charts are necessary when preparing forecasts up to four days ahead, framing the monthly monitoring bulletins.

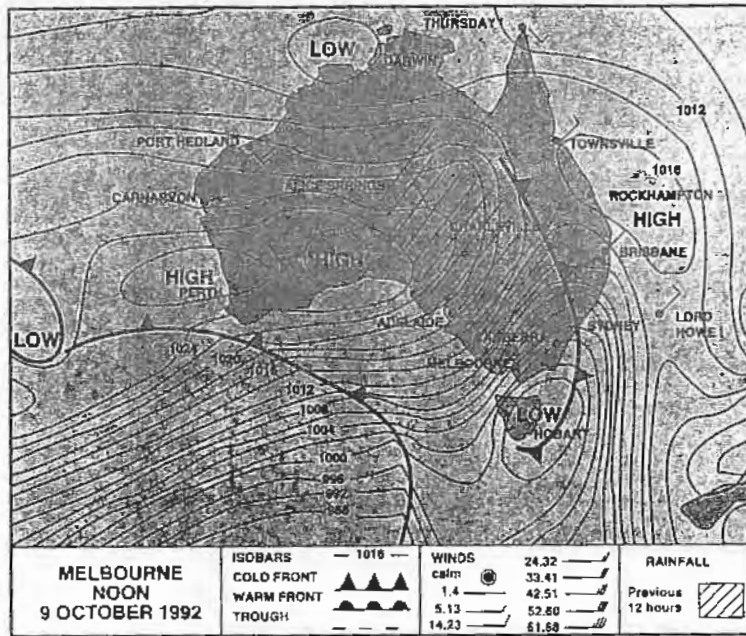


Figure 1 Typical newspaper weather map.

Typical weather map patterns

An understanding of some systematic weather patterns is needed when interpreting a map.

- **Easterly winds** over the tropics and subtropics incorporate wave-like disturbances which usually travel westward. Important features of the tropical easterlies include the southeast trade winds, monsoon lows and sometimes tropical cyclones (known as hurricanes in the Americas and typhoons in Asia).
- A **high pressure belt** in the mid-latitudes (usually 30-50 degrees latitude) contains centres of varying strengths which generally move from west to east. Fluctuations in the intensity of these highs ('anticyclones') strongly influence the behaviour of the trade winds and the development and decay of tropical lows.
- The **belt of westerly winds** south of the high pressure region contains disturbances

which usually travel from west to east. Barbed lines indicate the leading edge of travelling cold (and occasionally warm) fronts, the boundaries between different types of air. The term 'front' was applied during World War I by European meteorologists who saw similarities between atmospheric structures and the large-scale conflict along battle fronts.

- Nearer the pole, a **series of deep subpolar lows** is usually centred between latitudes 50-60 degrees South.
- A **high pressure area over Antarctica** — associated with extremely cold and dense air — is ringed by easterly winds which form the boundary with the subpolar low pressure belt.

These typical features vary in intensity and location according to the season. For instance, in summer the high pressure belt is usually found

just south of Australia, while the subtropical easterlies cover most of the continent. The flows and associated lows over the tropics are significant summer rain; tropical cyclones develop. In winter the high pressure belt is located over the continent, allowing strong cold fronts to affect southern

It is important to be alert to significant changes to this 'normal' situation when, for instance, strong high pressure systems move south of the oceans well south of Australia. 'Clock off' lows may then move across Australia or intensify over the Tasman Sea, possibly causing prolonged heavy rain.

It is also important to remember that weather systems have a life cycle of development, maturity and decay. They occasionally show unusual behaviour. They may become stationary or briefly reverse their usual direction of flow.

Hot or cold?

Remembering that air flows clockwise around low pressure systems and anticlockwise around high pressure systems, a fairly typical summer weather map (Figure 2) shows:

- **Northerly winds over eastern Australia** on the western flank of a Tasman Sea high. They carry hot, dry air from inland Australia southward over Victoria and Tasmania. With winds strengthening ahead of an approaching front, this represents a classic weather situation with extreme bushfire risk.

- **Moist, easterly flow** onto the Queensland coast causes very warm, humid and sultry weather east of the Great Dividing Range. This air, often susceptible to the development of showers and thunderstorms, is described as 'unstable'.
- The **cold front** passing South Australia replaces the hot, dry northwesterlies with southerlies carrying cooler, often relatively humid air from waters south of the continent.

Such summer fronts are often quiescent and may not penetrate far inland, especially if they are distorted and slowed by Victorian mountains.

In Figure 3, a relatively common winter weather map shows:

- **Very cold, unstable air** from the Tasmanian high flows northward over Victoria and southeast New South Wales, reducing normal day temperatures.

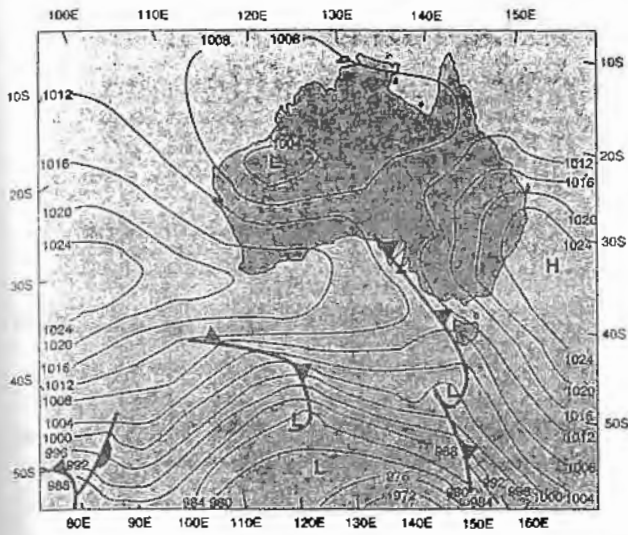


Figure 2 A summer weather map.

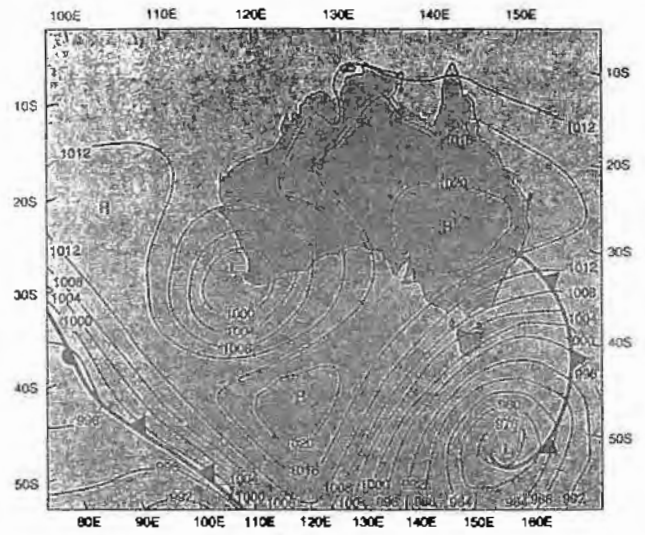


Figure 3 A winter weather map.

five degrees or more. Note the cold front, the deep low pressure (pressures below 976 hectopascals) south of Tasmania and the high (1020 hectopascals) south of the Bight. Occasionally, rapid interaction with other weather systems around the southern hemisphere can almost halt the pattern's eastward movement, causing successive cold fronts to

bring a prolonged spell of cold, showery weather to southern Australia.

- **Easterly winds** over inland Australia. Although southern cold fronts become shallow and diffuse as they move into northern Australia they often trigger a surge in the strength of the easterlies and this, combined

with their extreme dryness, creates a very high fire danger in the tropical savanna region.

- **active low pressure system** near Perth is 'cut off' from the southern westerlies. Situations of this type may cause rain and rather cold weather over southern parts of Western Australia.

Rain or fine?

Features on the surface weather chart indicate likely rainfall patterns as well as temperature distribution and wind strength. In general, highs tend to be associated with subsiding (sinking) air and generally fine weather, while lows are associated with ascending (rising) air and usually produce rain or showers.

While cloud can exist without rain, the opposite is not the case.

Clouds form by the condensation of water vapour through cooling. Causes of cooling include:

- **Convection**, which may be caused through air mass instability. It may be initiated by warming of low-level air, forced ascent over mountainous country, or dynamic causes associated with severe weather systems. Cumulus clouds often form as a result of convection. The most exceptional forms are often associated with severe thunderstorms and occasionally, tornadoes. Cumulonimbus, for instance, may reach altitudes above 15,000 metres.

- **Systematic ascent of moist air** over large areas linked with large-scale weather systems such as low pressure systems, including tropical cyclones. In mid-latitudes this systematic ascent often occurs ahead of active fronts, or with 'cut off' lows. This type of rain may be persistent and heavy and cause floods, especially if enhanced by forced (orographic) ascent over mountains.

- **Orographic ascent** which occurs when air is forced upwards by a barrier of mountains or hills. Cloud formation and rainfall is often the result. Australia's heaviest rainfall occurs on the Queensland coast and in western Tasmania, where prevailing maritime airstreams are forced to lift over mountain ranges.

- **Cold and warm fronts** which also cause systematic ascent. A cold front is the boundary where cold air moves to replace, and undercut, warmer and less dense air. Associated cloud and weather may vary enormously according to the properties of the air masses,

but tends to be concentrated near the front. As a typical cold front approaches, winds freshen from the north or northwest, and pressure falls. After the front passes, winds shift direction anticlockwise ('backing' to the west or southwest) and pressure rises. Cold fronts are much more frequent and vigorous over southern Australia than elsewhere. Warm fronts, relatively infrequent over Australia, are usually found in high latitudes where they can occasionally cause significant weather. They are often shown on weather charts over the Southern Ocean. Warm fronts progressively displace cool air by warmer air.

- **Convergence lifting** which occurs when more air flows into an area at low levels than flows out, leading to forced rising of large air masses. Convergence is often associated with wave-like disturbances in tropical easterlies and may also occur with broad tropical air masses flowing to the south. Given sufficient atmospheric moisture and instability, it may cause large cloud clusters and rain.

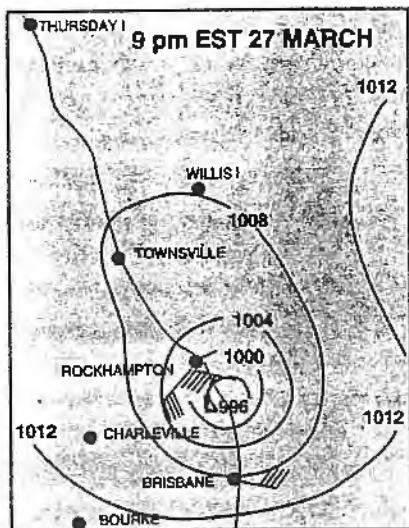
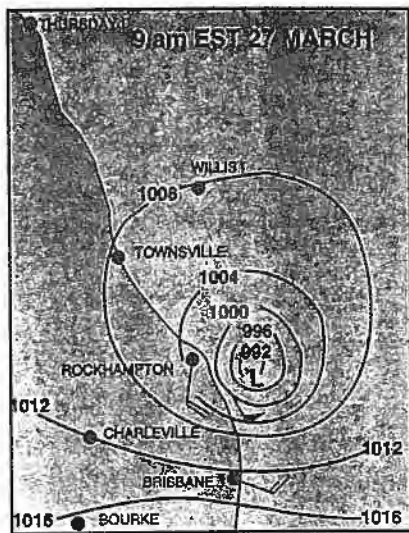
How strong will the winds be?

A mean sea level pressure chart shows the direct relationship between isobar spacing (pressure gradient) and orientation, and the strength and direction of surface winds. The general rule is that winds are strongest where the isobars are closest together. Thus the strongest winds are usually experienced near cold fronts, low pres-

sure systems and in westerly airstreams south of the continent. Winds are normally light near high pressure systems where the isobars are widely spaced.

However, because of a latitude effect winds in middle latitudes are lighter than those in the tropics with similarly spaced isobars.

In Australia, the most destructive winds over broad areas are generated by tropical cyclones. (Tornadoes, associated with some severe thunderstorms, have the potential to generate higher wind speeds, but areas affected are much smaller than these tropical storms.)



Figures 4 (a) and (b) Charts of a cyclone moving from the Coral Sea to the Queensland coast demonstrate how isobars indicate wind speed and direction.

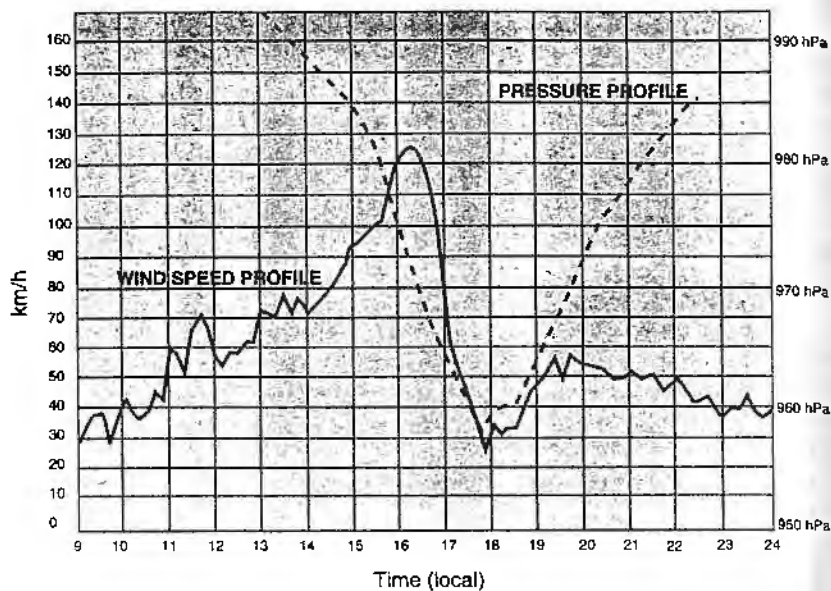


Figure 5 Typical wind speed and pressure relationships for a tropical cyclone - cyclone Winifred, Cowley Beach, Queensland, February 1986.

Tropical cyclones are low pressure systems in the tropics which, in the southern hemisphere, have well defined clockwise circulations with mean surface winds (averaged over ten minutes) exceeding gale force (63 kilometres per hour) surrounding the centre. Tropical cyclones exhibit a relatively clear eye, surrounded by dense wall clouds and a series of spiral rain-bands. The Bureau tracks cyclones with weather watch radar, special service reports and frequent satellite images. Figures 4(a) and (b) show a tropical cyclone approaching, and crossing the Queensland coast near Rockhampton. The pressure gradient is very steep towards the cyclone's centre and wind

speeds on the nearby coast in this case would have been about 110 kilometres per hour with gusts 50 per cent or more above this mean wind speed. In Figure 4(b), 12 hours later, the cyclone has moved inland. Cut off from its heat energy source, the ocean (it requires sea-surface temperatures above 26.5°C), its intensity has decreased and wind speeds have dropped to 85-90 kilometres per hour. Figure 5 graphs the relationship between wind speed and pressure as the eye of tropical cyclone Winifred crossed Cowley Beach, in Queensland, in February 1986. The relationship is characteristic of tropical cyclones.

Using weather charts

Preparation of weather charts which predict surface and upper level flow patterns up to several days ahead is integral to weather forecasting. The best and most objective way of doing this is to use computer models incorporating the equations which represent the motion of the atmosphere, and its associated physics. The Bureau's supercomputers run mathematical models on a global and regional scale for both daily forecasting and for research.

While predicted (prognostic) weather charts are essential to the forecast process, they must be interpreted by meteorologists to prepare specific

weather forecasts and warnings. Forecast errors still occur, due to limitations in data or the forecast models, and the inherent complexity of the atmosphere, but forecast accuracy has increased very significantly since the introduction of satellite information and mathematical modelling. Prognostic charts shown routinely on television and in newspapers predict conditions up to three days ahead.

An inexpensive aneroid barometer enables weather map watchers to follow changes in surface air pressure over time, giving important clues to subtle alterations in weather systems.

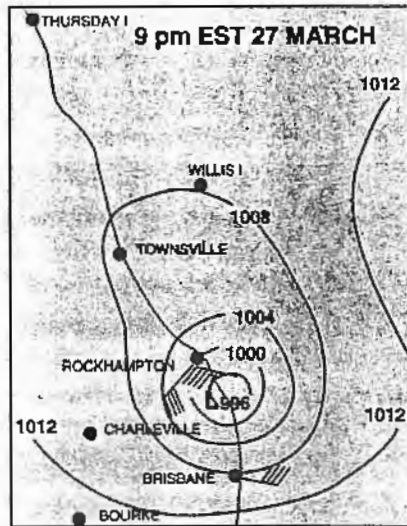
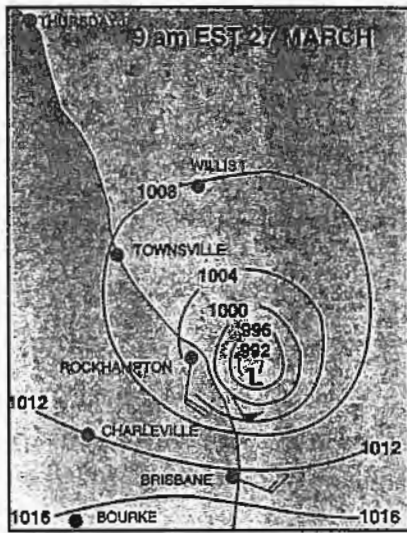
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It will be realised by now that a single weather map is only a forecasting aid and that a great deal of other data and information must be gathered and processed before a forecast is issued. However, the information in this leaflet should assist in understanding and interpretation.

For further information contact the Bureau of Meteorology Regional Office in your State or Territory

SECTION B3

**Pesticide formulations
and selections**



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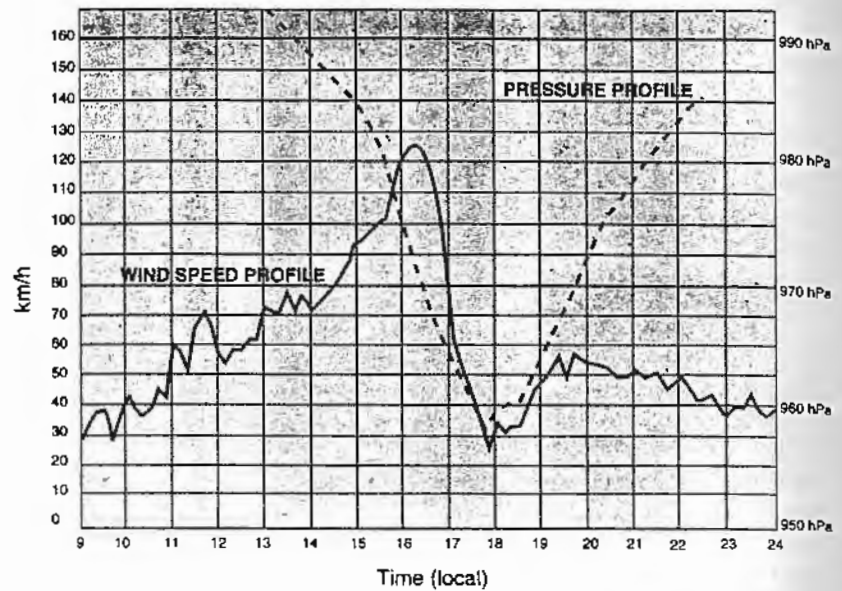


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SECTION B3

**Pesticide formulations
and selections**



PESTICIDE FORMULATIONS AND SELECTIONS

Introduction

As we have seen the cotton farm chemical market is dominated by the challenge of insect pest management and there is also significant use of herbicides to control weeds prior to and during crop development. Fungicides are only of minor importance and mainly used by seed suppliers for protection of that stock from seed-borne diseases.

1. The range of pesticides available

Any chemical marketed for the purpose of protecting cotton from pests must be registered for the purpose which implies approval by the National Registration Authority (N.R.A.). This in turn means that, if label directions are followed

- (a) the crop will be protected efficiently from pest competition and attack;
- (b) people handling the product will not be put at risk;
- (c) the off-target impact on the environment will be minimal.

Label directions are designed to achieve these ends but they can always be re-inforced by further managerial common-sense.

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.

2. Formulations

Very few farm chemical actives are manufactured from basic elements in Australia but many are formulated by manufacturers who import the various components. The products marketed are expected to remain stable and true to label specification for at least two years under reasonable storage conditions in 'the trade' and, in fact, many remain stable for much longer periods. As we have seen in Section A2, cotton chemicals are available in many different formulations and the properties of these necessitate different handling techniques—be they solid powder or granules—suspensions, liquids. This section will look at how to manage these to best advantage.

2.1. Current trends

- (i) Problems with plastic container disposal is having a significant influence on trends in formulations at the present time. Manufacturers are attempting to move away from liquid concentrates towards granular, crystal and gel formulations. This is because these alternatives lend themselves to being packed in lined cardboard packs and/or in water soluble pre-packs which eventually make outer container disposal much more straight forward.
- (ii) Another trend that is currently evident is the result of restrictions being placed on the transport and storage of flammable liquids. Until recently both toluene and xylene have been widely used as solvents in many insecticide formulations. The products containing them have flash points of less than 61°C which classifies them as Class 3 dangerous goods with accompanying constraints in transport, storage, compatibility and insurance. These two solvents are now being replaced wherever possible with newer less flammable solvents such as "Solvesso 150" from the Exxon Oil

Company which has a flash point of 150°C thus **not** qualifying for the Class 3 red diamond. Molecules because of their nature are locked into certain flammable solvents such as "Lannate®" which uses methanol and "Velpar®" which uses ethanol both with flash points below 20°C.

2.2. Cotton herbicide formulations

2.2.1. Aqueous solutions e.g. "Banvel®", "Gramoxone®", "Spray-Seed®"

Water based concentrates such as dicamba, paraquat and diquat are stable, mix easily and need no agitation once a spray solution has been made up. Paraquat and diquat are reactive 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.

2.2.2. Liquid concentrates e.g. "Roundup®"

Glyphosate like paraquat and diquat can be inactivated by being bound to clay particles. Clean water is a must. Again once a spray solution is made up agitation is not required to maintain a spray liquid with the active component equally spread throughout its volume.

2.2.3. Suspension concentrates e.g. "Diuron 500SC®" and "Cotoran 500®"

These formulations are sometimes known as 'flowables'. When first introduced they represented a significant advance on powders in that potentially hazardous dust was eliminated and the liquid suspension could be poured and measured accurately by volume.

Flowables need vigorous shaking to make sure the drum contents are homogeneous before measuring out. Drums of flowables that have remained in stock undisturbed for quite short periods (weeks) tend to slowly settle out and must be shaken before use.

2.2.4. Water dispersible granules e.g. "Diurex 900 WG®"

This popular formulation is used for an increasing number of chemicals. When low toxicity chemicals are involved the granules can be concentrated with up to 90% active which makes for high efficiency in transport and storage—an improvement factor of 1.8 when compared with flowables in terms of active.

$$\text{WD Granule} \quad 900 \text{ g/kg} \frac{9}{5} = 1.8$$

$$\text{Flowable} \quad 500 \text{ g/L}$$

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

2.2.5. Wettable powders e.g. "Diuron 800"

Wettable powders are becoming less common but at one time dominated the solid formulation scene. The active constituent is milled to a fine (5 µm to 10 µ) consistency and then blended with dispersants, surfactants and some inert carrier. Most mix with water easily and quickly if given good agitation in the spray vat.

2.2.6. Emulsifiable concentrates e.g. "Fusilade®", "Verdict®", "Sertin®"

Unlike the previous three groups these are true liquids but of a sort known as emulsions. In the case of an EC the active constituent is dissolved in a solvent or petroleum oil and then, blended with a special surfactant or emulsifier. When mixed with water the product disperses as millions of minute droplets of oil each containing a small amount of the active ingredient to form an emulsion with the water. The 'milky' colouring that appears as an EC is added to water, is characteristic of the formulation. Good ECs mix easily and stay dispersed evenly without agitation after the initial stirring of the spray. However, once made up into a spray solution it is advisable to apply ECs soon after as if left standing for several hours, it is possible for some separation of the oil and water fractions to occur. This will be indicated by an oily scum forming on the surface of the milky coloured solution.

2.3. Cotton insecticide formulations

2.3.1. The ULV or ultra low volume formulation

Most cotton insecticide spraying is carried out when the weather is hot and the problems of droplet evaporation associated with high temperatures will be present. One answer is to apply the spray in a low evaporative carrier (oil) rather than water. Using delivery systems on aircraft such as Micronairs, it is possible to achieve coverage of pests with volumes as low as 2 L to 5 L per hectare. Products presented in this type of formulation are designed to be moved straight from the pack in which they have been delivered into the aircraft vat for subsequent application. They need no intermediate handling and therefore lend themselves to closed handling systems and a high level of safety to applicators. Generally ULV formulations are not applied by ground rigs.

The major chemical insecticide groups nearly all have a ULV formulation available.

These ULV formulations are largely exclusive to the Australian cotton industry where low volume aerial application is still used efficiently. (Refer Cotton Pesticides Guide 1994).

2.3.2. Soluble powder e.g. "Orthene®"

This organo-phosphate insecticide is sold as a completely soluble white powder which dissolves in water to form a true liquid.

2.3.3. Granules e.g. "Temik®", and "Thimet®"

Chemicals with high technical efficiency in pest control but with associated high levels of mammalian toxicity need a special formulation to lower the risk to applicators and the environment. Two such are aldicarb which is sold as Temik® and phorate sold as Thimet®. In both cases the product is a low active granule where 80% to 90% of the contents are inert and the 10% to 20% of active material is distributed through this inert mass to lessen the chances of contact in the event of accident. Even so, these products need special care in storage and handling particularly from the point of view of keeping them dry until used.

2.3.4. Bio-formulations e.g. *Bacillus thuringiensis*

The only currently widely used bio-formulation is *Bacillus thuringiensis* which is marketed by a number of companies. *Bacillus thuringiensis* has been available for a long time but until recently has never had a commercially viable level of acceptance because of its mode of action. It is slower to kill and has lower kill percentage than most synthetic insecticides.

2.4. Mixing and applying cotton chemicals

2.4.1. Read the label

The first step in every case is to read the label and proceed by following its directions.

2.4.2. Agitation

When ever a solid active constituent is used as in wettable powders, dispersable granules or suspension concentrates good spray vat agitation will be needed to keep the spray output consistent in strength. Failure to do this will result in varying degrees of gravity effect as the active settles towards the bottom of the vat during the spraying operation.

2.4.3. 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. There are a number of factors that must be borne in mind when judging water suitability and these are:

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. In the case of the non-residual herbicides glyphosate, paraquat and diquat binding to the clay is such that the active chemical is no longer free to work on its target weed. In other cases a looser binding called **adsorption** can occur which may temporarily prevent the entire tank pesticide dose being available for use. It is advisable to use only clear settled water for sprays and if none is readily available, consider the possibility of using alum to flocculate and sink the suspended solids present.

Water acidity/alkalinity

Two of the major insecticide chemical groups - the organo-phosphates and the carbamates degrade by hydrolysis - interaction with water - when they come into contact with water that has an alkaline nature. 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 have appeared on the market to counter this destabilising effect but to work out dose rates an accurate idea of the pH needs to be obtained.

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.

Testing for water quality

Water quality and suitability should be known by having samples tested for pH and chemical content.

2.5. The use of adjuvants

An adjuvant is any substance added to a spray mixture to modify its performance and usually enhance it or overcome some inhibiting factor.

2.5.1. Wetting agents

Labels will always indicate whether a wetting agent or surfactant is required. This may be dependent on the volume applied. Non-ionic wetters are normally used.

2.5.2. Buffering agents

Some chemical groups including the organo-phosphate 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 over 7.

2.5.3. Crystalline sulphate of ammonia (under some circumstances)

Monsanto recommend the addition of 2 kg of sulphate of Ammonia per 100 L spray volume to "Roundup ®" sprays. It promotes consistent performance and assists in overcoming antagonism in certain mixed sprays.

2.6. Using more than one chemical together

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 pesticide chemicals 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 on this subject is usually available from chemical companies on request.

Mixing 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.

- 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 proven only by extended previous use in a range of situations.
- Where information is unavailable, and mixtures unavoidable, use the test outlined below as a rough guide for assessment of possible mixture problems. 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:

First	Wettable powder or water dispersible granule or soluble powder
Second	Suspension concentrate (flowable) or miscible liquids
Third	Adjuvants or wetters/ spreaders/ stickers and finally
Fourth	Emulsifiable concentrates or crop oils

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 above.

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 be abandoned.

2.7 Strategies with chemicals

When using chemicals it pays to know as much as possible about the behavioural characteristics of any formulations selected. The prime source of this information is the label and a close back up is the material safety data sheet (MSDS) available at the time of purchase from the supplier. Any queries after reading these two documents are best answered by the technical service people of the manufacturer.

SECTION B4

**The use of aircraft for
cotton pesticide application**



THE USE OF AIRCRAFT FOR COTTON PESTICIDE APPLICATION

Introduction

There are currently about 275 aircraft registered in Australia for the application of pesticides. These specialist aircraft, flown by pilots from about 100 aerial application companies, apply pesticides and fertilisers to about 8 million hectares annually. Although highly dependent on seasonal conditions, it has been estimated that the total crop protection pesticide market in Australia in an average year is worth approximately \$700 million per annum at the farm gate. About 20% of this is applied by air but proportionally the figure is far higher and may reach as high as 45% in the cotton industry. A survey conducted a few years ago by the Centre for Pesticide Application and Safety showed that in the Eastern States more aerial operators were involved in cotton spraying than any other crop.

The case for using agricultural aircraft is well documented (Table B4-1). Their use in post-war agriculture, particularly cotton, has developed largely as a result of the greater speed, better timing and efficiency of application offered by an airborne platform. Crossing the ground at about 200 km/hr, aircraft are able to apply agricultural products rapidly over large areas within narrow optimum application windows. When crop height and irrigated areas restrict the passage of ground based spray rigs, aircraft are able to place pesticides strategically on crops in response to economic thresholds without contributing to soil compaction and structural breakdown. Australia arguably now leads the world in some aspects of ultra low volume (ULV) technology and uses some of the largest, safest and most powerful specialist aircraft available.

1. Aircraft types

The range of aircraft used in Australia's cotton industry is noteworthy. Depending on location, the cotton grower will see a number of different types of aircraft being used in the industry. Some aerial operators use medium sized aircraft such as the Cessna Agrtruck (AgHuskey) and Piper Pawnee Brave. Fitted with 400 HP air cooled engines these aircraft can lift about 1000 kg of material. Particularly where high utilisation can be obtained over extensive cotton growing areas, larger 600 HP Air Tractors and Ayres Thrushs can be seen fitted with large radial piston engines. Over the last few years 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 turbine powerplants are now common place in most cotton growing areas. Turbine engines are lighter and more powerful than equivalent piston engines, quietly turn 3 and 5 bladed propellers and generally have lower direct operating costs. Capable of lifting in excess of 2 tonnes of product (in the case of the AT502 and T65 Thrush) these aircraft are the 'quiet achievers' of the aerial agricultural industry. It should be noted however that turbine engines are expensive and a new aircraft can cost US\$350-500,000 to purchase, and the engine comprises about 30-50% of this amount.

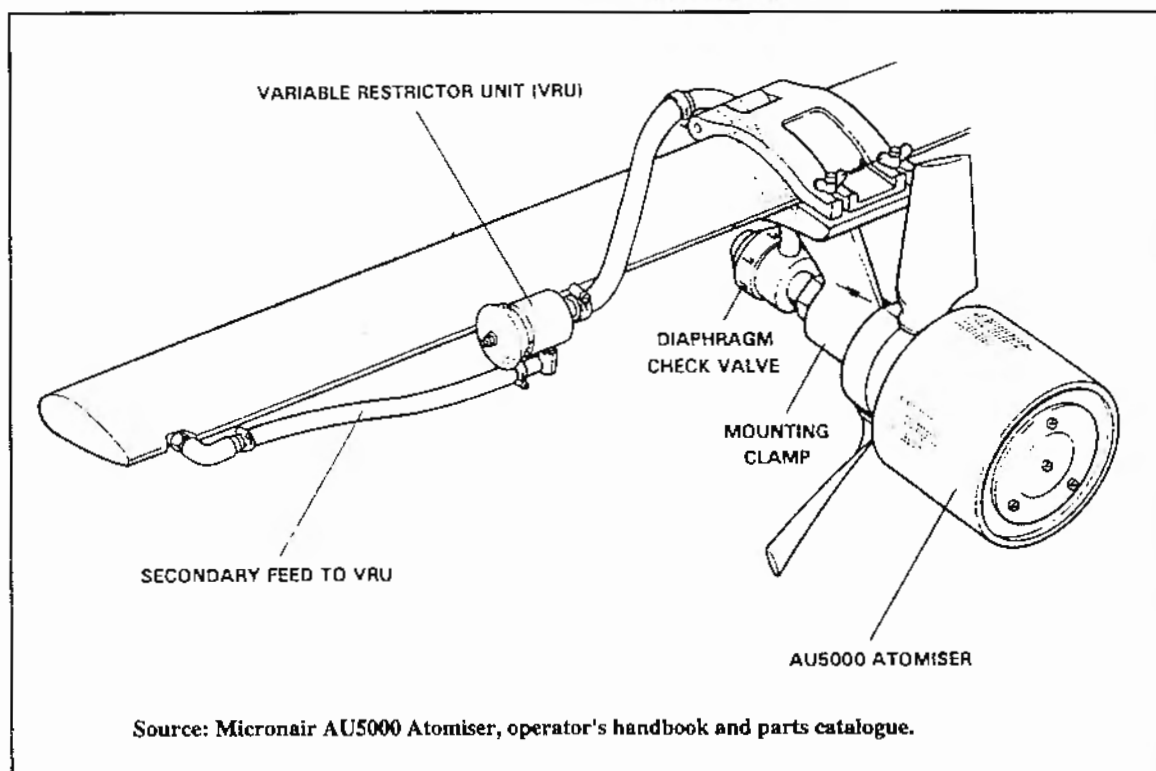
Table B4-1. Some advantages of using agricultural aircraft for pesticide application

1.	Aircraft can be used over wet areas, impassable to a wheeled vehicle.
2.	Being clear of the ground, soil impaction and wheel marks are eliminated.
3.	Aircraft are faster and more fuel efficient.
4.	Airborne application allows timely treatment of pests and diseases.
5.	Better coverage and penetration of a crop is often achieved.
6.	Grower labour is reduced.
7.	Aircraft can overcome limitations when crop height acts against ground based equipment.
8.	A grower can have the additional facility of conferring application to skilled professional operators with correctly calibrated equipment.

2. Application equipment

Cotton insecticides, herbicides and defoliant are applied to cotton using both hydraulic nozzles and the centrifugal energy Micronair AU5000, (Figure B4-1). The latter has been widely adopted in Australia due to the ability to change the size of droplets it emits. This advantage, together with the ease with which it handles most agricultural formulations has resulted in its widespread adoption in the cotton industry. Droplets generated by the Micronair AU5000 are normally less than 250 μm (VMD), (Section 5), which makes the unit very suited to both low volume (LV) and ultra low volume (ULV) insecticide application. Aircraft are normally equipped with 8 to 12 units.

Figure B4-1. Diagram of typical installation



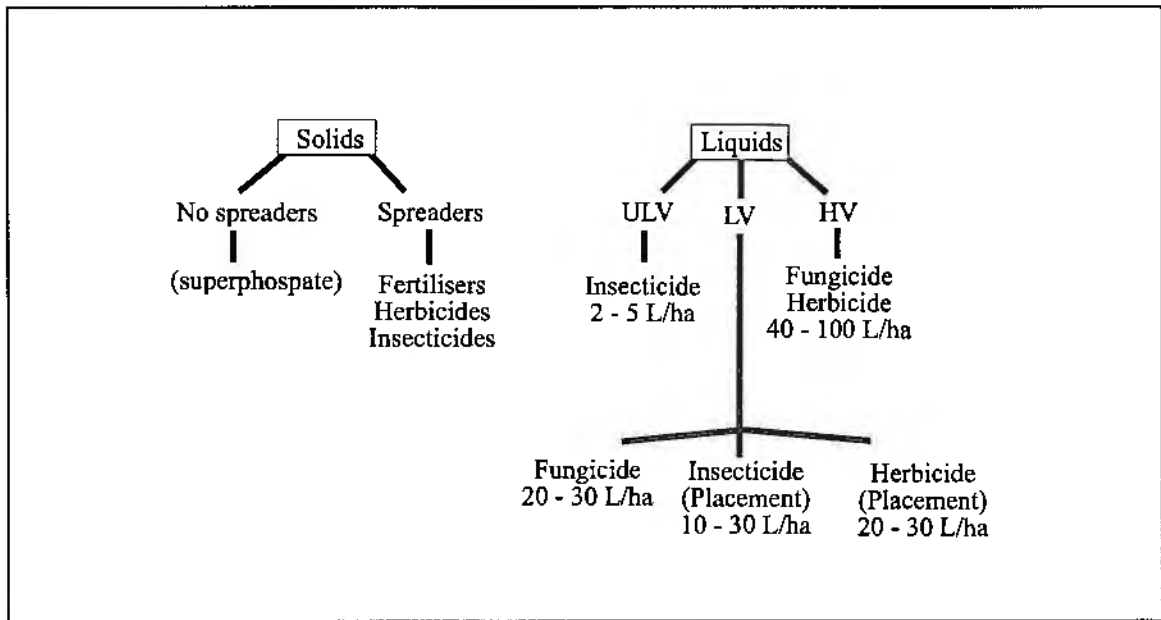
Hydraulic nozzles such as spraying systems hollow cones (D series), large orifice flat fans and the CP variable flowrate nozzles are also used on aircraft. An aerial operator will normally set up his aircraft with about 20 to 50 hydraulic nozzles depending upon nozzle type, required flowrate and the need to balance the spray pattern underneath the aircraft to counteract the influence of the airflows about the airframe. In general, larger droplets (VMD) are capable of being generated by hydraulic nozzles (250–500 μm) and thus they are used primarily for herbicide and defoliant application. The actual droplet size produced is highly dependent upon the angle at which the nozzles are angled relative to the airstream. 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 airshear nozzle in a misting machine (Section B1). It should be noted that many small droplets can be generated with both Micronair and hydraulic nozzles and the potential for off-target movement should always be considered—as with ALL spray application.

Solid formulations of fertilisers can also be applied by air by means of special delivery systems. Aerial operators normally use some form of gravity fed ram-air spreader 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.

3. Aerial application technology

Figure B4-2 shows a simple summary of how aircraft are used in agriculture in Australia.

Figure B4-2. Aerial application of pesticides



In the cotton industry there are two basic technologies used by aerial operators to spray liquid insecticides and herbicides *viz*, placement and wide swath spraying. These two techniques based on the physics of droplet behaviour, are used to apply pesticides to cotton in four main ways.

1. Placement (LV) spraying of herbicides
2. Placement (LV) spraying of insecticides (e.g. EC formulations)
3. Wide swath (ULV) spraying of insecticides (mature cotton)
4. Wide swath (ULV) spraying of insecticides (immature cotton)

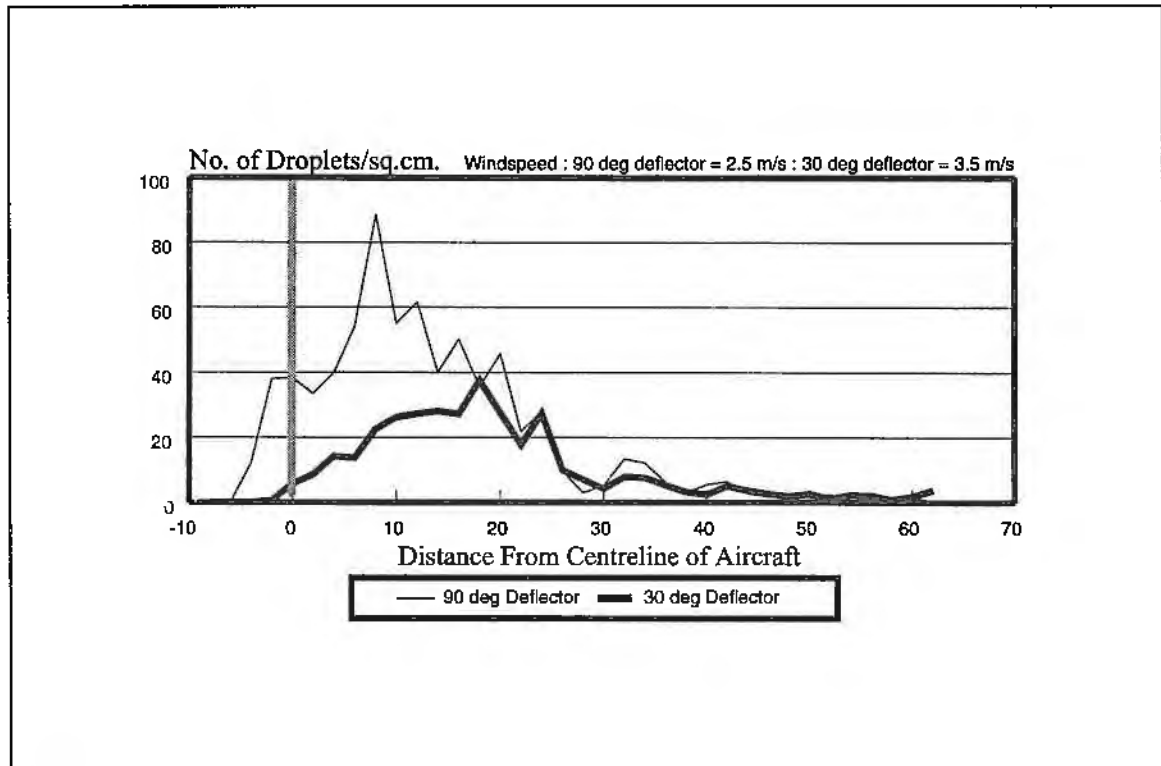
4. Placement spraying

As shown in Section B1, large droplets have a high kinetic energy and fall towards the ground under the influence of gravity at high terminal or sedimentation velocities. Since large droplets fall relatively fast towards the ground and are not greatly influenced by vertical air movement and turbulence, their trajectory can be calculated with a reasonable accuracy. If large 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'. Generally such application is undertaken using emulsifiable concentrates (EC's) or wettable powders (WP's) using total application rates of water 20–30 L/ha. Herbicides are nearly always applied using this technique. This type of application is best carried out when conditions provide light winds with low temperatures (say <25°C) and high relative humidities, (say >65%). The aircraft has to fly accurately across the paddock to ensure an even and smooth deposit is 'painted' onto the crop. As might be expected this type of deposition 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 defoliants when the crop itself becomes, to all intents and purposes, another weed.

On occasions, such as where sensitive areas are located immediately downwind of a cotton field, this application technique is used for EC insecticide formulations. When this approach is adopted, 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 meteorological conditions and in a neutral atmosphere (see Section B2) to prevent excessive evaporation.

Figure B4–3 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° and then 90°. The graph shows clearly that a larger number of droplets were deposited when the 90° deflector plate was used. This is because the larger angle caused the spray to be diverted into the airstream causing the liquid to be broken up into smaller droplets. The smaller droplet size has resulted in a larger number of droplets being deposited.

Figure B4-3. Droplet distribution pattern, CP nozzles, cross wind



If placement (herbicide) application was being undertaken, the 30° deflector plate would be the most appropriate setting. Larger droplets could be deposited more evenly across the ground as long as a flight lane separation was adopted that allowed the pattern to be overlapped across a paddock such that a uniform deposit was obtained. The Centre for Pesticide Application & Safety routinely conducts tests for aerial operators to establish optimum flight lane separation (FLS) values and deposit levels for specific aircraft and nozzle systems

5. Wide swath (ULV) spraying

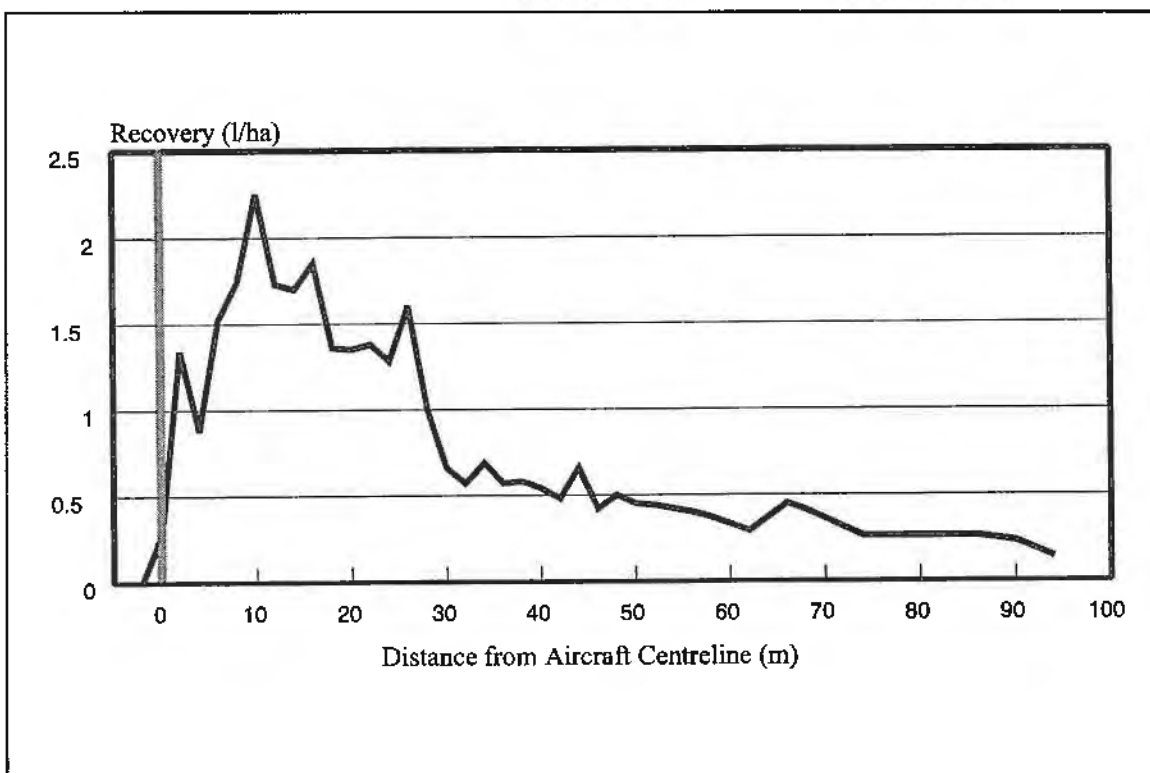
Insecticide sprays are more commonly applied in cotton utilising the natural (mechanical) wind generated turbulence present above the crop canopy to distribute the droplets about the target. Pesticides formulated in oil based low volatile carriers are applied 'straight from the can' at total application rates of 2–5 L/ha. This low rate of carrier is achieved by generating small droplets (say 50–100 µm VMD). Such droplet sizes allow large numbers of droplets to be generated thereby compensating for the low volume of carrier. The technology can be highly efficient and lead to decreased application costs as a result of fewer take-offs and landings and less ferry time being required per litre volume applied.

Since a prevailing wind moves mainly horizontally across the top of a crop, small 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. The biology of pest species such as *Helicoverpa* is such that droplets deposited in this way can be readily intercepted by feeding larvae.

It is often assumed that in a wind all the fine droplets contained in a spray cloud will be blown huge distances downwind. However this is not usually the case. 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 close to the release point, (for example 20 metres from the line of flight of an aircraft). This is because the droplet cloud is expanded by the turbulence and brought quickly towards the ground. It should be noted however, that 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.

By way of example Figure B4-4 shows a ULV deposit pattern recovered from the top canopy of a mature cotton canopy using fluorometry. A single application run of Larvin® LV was applied to the cotton in a 90° cross wind at 5 L/ha using a Turbine Thrush fitted with 10 Micronair AU5000 units. The droplet spectra 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 extracted from leaf surfaces after application to illuminate 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 FLS and deposit data.

Figure B4-4. Canopy distribution pattern, INSECTICIDE ULV (4L/ha) In mature cotton



6. Extended flight lane separations

Where very young cotton is sprayed, it is possible for aircraft to fly across a paddock using wider swath widths or more correctly extended flight lane separations (FLS). Experiments have shown that when canopies are immature, and less than about 30 cm tall, coverage of the developing plant can be obtained at wider than normal flight lane separations. Such techniques allow application costs to be reduced, however application should only be undertaken under recognised conditions and with the full co-operation of consultants and direction of the aerial operator.

7. Aircraft operating conditions

As a guide to the efficient management of aerial application, Table B4-2 sets out basic requirements and parameters required for placement and wide swath spraying of pesticides in cotton. The table is intended to show four techniques that can be used in cotton. Note that these are **intended as a guide only** and some parameters such as droplet size and effective swath widths for example, will depend upon formulations, application equipment and weather conditions experienced in the field.

Table B4-2. General guidelines showing principle aerial application techniques used in cotton

	(1) Placement (LV) Herbicides & Defoliants	(2) Placement (LV) Insecticides	(3) Wide Swath (ULV) Insecticides (Mature)	(4) Wide Swath (ULV) Insecticides (Immature)
Spray Volume (L/ha)	20-40	20-30	2-5	2-5
Flight Direction	cross wind*	cross wind	cross wind	cross wind
Droplet Size VMD (μm)	250 +	150	80-100	50-100
Nozzle Type	Hydraulic Nozzle	AU5000	AU5000	AU5000
Lane Sep. (FLS) (m)	Correct placement overlap**	Correct placement overlap*	Correct wide swath overlap*	Correct extended wide swath overlap*
Wind Velocity (m/s)	2-3	1-5	2-5	2-5+
Temperature ($^{\circ}\text{C}$)	< 32	< 32	<32 (not as critical)	<32 (not as critical)
RH (%)	High >50	High >50	-	-
Stability	Neutral	Neutral	Neutral-slightly unstable	Neutral-slightly unstable

* Where possible. Subject to operational constraints, e.g. field layout and obstructions, etc.

** Correct overlap is best determined from an analysis of ground and crop deposition patterns.



SECTION B5

**Maximising the
effectiveness of aircraft**

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MAXIMISING THE EFFECTIVENESS OF AIRCRAFT

Introduction

In deciding to use an aircraft for the application of pesticides on his crop, the cotton grower will contract a professional aerial operator to undertake the spraying on his behalf. The use of aerial operators who are members of the Aerial Agricultural Association of Australia (AAAA) and involved in the Operation Spraysafe program is strongly recommended. The agricultural pilot is responsible for most aspects of the pesticide application, however the cotton grower should liaise with the aerial operator in the planning stage and fully brief the pilot or operations manager on paddock layout and flying hazards such as powerlines. In addition, the grower should identify areas which could be susceptible to spray drift, whether they be neighbouring crops, water ways or buildings and bring these to the attention of the operator during early stages of the planning process.

A key to successful incident free application is communication and the grower should strive to maintain adequate and open communication with the pilot, ground staff, consultants, neighbours and the community at all times (if involved in the spraying decision making process). Both the operator, consultant and grower have a shared responsibility to ensure that application is always undertaken as safely and efficiently as is possible. For example, growers should attempt to liaise with bee keepers to prevent accidental spraying of hives or crops in which bees are actively foraging.

1. Application windows

Preceding sections on aerial application show that optimum times for application exist during each 24 hour period. These time slots are sometimes referred to as 'windows'. The time length of a window will depend on local meteorological conditions and the type of application that is to be undertaken. Most aerial operators will strive to maximise output when application conditions are an optimum and thereby attempt to achieve maximum deposit levels on the target. The grower should be aware however, of the following points:

1. Aerial operators will normally attempt to complete aerial application within defined windows, therefore the grower should sometimes be prepared for delays if work loads are high and meteorological conditions a constraint.
2. Because of a natural concern for the environment and stricter controls on aerial spraying, sometimes growers may have to wait several days for conditions to become favourable for spraying. For example, if a particular wind strength or direction is required to prevent spray drift into a susceptible area, an operator may elect to wait and postpone the operation until the desired conditions exist. In such circumstances the grower is encouraged to liaise with the pilot, be patient under the difficult circumstances and avoid the temptation to find another pilot who will 'do the job—no questions asked!'. Unfortunately although tens of thousands of hectares are sprayed satisfactorily every season, one incident causing damage may cause major publicity and reflect badly on the whole industry. Most growers will be familiar with one or more incidents when emotional reporting has created a difficult situation for the industry. It pays everyone to try their best to stop this scenario arising. Note that just occasionally delays in application may necessitate an adjustment in dose of chemical applied to account for the increase in size (biomass) of the scheduled target.

3. Where application by air is difficult e.g. close to bends in rivers or close proximity to water courses, the grower may have to use alternative crop protection strategies and probably ground spraying to reduce the potential for off target spray movement.
4. Aerial operators can schedule most jobs given sufficient time to plan and co-ordinate aircraft. The early notification of spray mission requirements by growers and consultants is strongly encouraged to make planning as efficient as possible.

2. Marking

Many aerial operators in the cotton industry employ professional marking teams to mark swath width or more correctly, flight lane separation (FLS) distances in the paddock. Alternatively, some pilots use a system of permanent flags, usually located on two parallel boundaries of the paddock. Occasionally the operator may request the assistance of the grower to flag a paddock. The following check list reproduced with permission from the AAAA Pilots and Operators manual, sets out some important points that should be noted by any person undertaking the marking or flagging of an agricultural aircraft.

1. Correct protective clothing must always be worn. As a minimum this should consist of a clean overalls (preferably white), boots and a washable broad brimmed hat.
2. If toxic chemicals are being used an appropriate respirator should be worn (Section A3). These should comply with Standards AS 1716 – 1991.
3. The marking start position must be established with the pilot together with the swath distance and direction of marking.
4. When possible the pilot will fly the paddock crosswind and ensure that the marking direction (that of the marker) is into wind so that any spray movement is away from the marker.
5. A coloured flag (red, yellow or white) should be used, a torch or flasher unit at night. Spare bulbs and batteries must be carried.
6. If possible the marker should stand back about 50 metres from the edge of the crop. He or she should signal to the pilot by waving vigorously whilst the aircraft is completing its turn and once it has lined up immediately pace out the next marking distance.
7. A marker should move off just as the aircraft's wings are level coming out of a turn, or when the aircraft is a minimum of 300 metres away on a spray run.
8. It is preferable not to mark under power lines but if this is unavoidable it is imperative to clear the flight path as early as possible.
9. If for some unavoidable reason it is impossible to clear the flight path of the aircraft, the marker should lie face down on the ground with hands and head beneath the flag. the marker should cease marking, wash exposed parts of the body and change into clean clothing.
10. Ground crew if possible should not touch or walk through the sprayed crop to avoid skin contamination with the chemical.
11. The pilot should advise the marker if an on-board smoke generator is to be used for assessing wind velocity, this may avoid a lapse of concentration.
12. As soon as the marking is complete, the marker should wash thoroughly before eating, drinking or smoking. A change of clothes at the earliest opportunity is recommended.

3. Biological buffer zones

The use of biological material, plant foliage in particular, to assist with the management of small spray droplets under 100 μm , which may have the potential to move out of sprayed areas was proposed as a concept in the late 1980s. This concept has been investigated using funding supplied by the Cotton Research & Development Corporation. Initially wind tunnel experiments and mathematical modelling were used to define height and porosity parameters. This was followed by a series of in-field measurements using plant foliage in real spraying situations.

The outcome of this work has been the recommendation that cropping areas be surrounded by buffer zones containing open plantings comprised of plants with slender rough foliage which will attain a minimum height of 1.5 times the height of spray release. The plantings should be randomly placed in an open pattern along a band 30 m wide and consist of appropriate shrubs and small trees.

The general principles related to the establishment and maintenance of biological buffer zones have been widely promoted. Several local authorities have included as a requirement, the establishment of biological buffer zones designed to assist with the management of small droplets, for the sub-division approval of areas which adjoin agricultural/horticultural enterprises. In addition, several cotton growers are in the process of establishing biological buffer zones and the Forestry and Land Management agencies are promoting the revegetation of the landscape using the principles of biological buffer zones. Lists of plants suitable for various regions with the characteristics required to be effective in buffer zones are currently being developed.

Popular articles describing the principles and benefits of the establishment of biological buffer zones are in preparation which will further expand the information already included in the Cotton Grower, Vol. 12 No. 3 titled 'Biological Buffer Zones Offer Many Advantages'. For more information contact Plant Protection Section, The University of Queensland Gatton College, telephone (074) 601 281.

4. Drift control

The importance of sound spray drift management cannot be over emphasised. Although it is important to maximise recovery of pesticides in the crop for reasons of efficacy, it is equally important that every application is undertaken in such a way that the off target movement of pesticides is minimised. To assist the grower in reducing the possibility of spray drift, and encourage sound management practises the following points summarise preventative measures. The procedures listed can be used for both ground and aerial application.

1. Wherever possible identify all susceptible areas within a cropping system.
2. The correct wind direction selected, should be away from all susceptible areas.
3. For maximum drift control ensure only larger droplets ($> 250 \mu\text{m}$) are generated (see Section B1 and B2).
4. The correct meteorological conditions should be present, low temperatures (e.g. $< 30^\circ \text{C}$) and high humidities ($> 50\%$). (See Section B2).
5. Optimum wind conditions should be present (see Section B2).
6. Application equipment should be correctly calibrated. The aerial operator is responsible for determining the correct flowrate and flight lane separation. The pilot is also responsible for positioning his aircraft accurately over the target area and ensuring that application equipment is functioning correctly.

7. If necessary appropriate buffer zones should be left between the target area and downwind sensitive areas. As a last control measure, suitable buffer vegetation should be used wherever possible to limit the movement of droplets into susceptible areas.

It should be remembered that the variables associated with spraying interact with each other in a complex fashion which means that a recipe for all spraying situations cannot be given.

5. Future developments

The next few years will see significant changes in application technology in the cotton industry particularly regarding the aerial application of pesticides. There will be a trend towards improving accuracy, developing mathematical equations to predict deposit levels and drift potential and an increase in the use of computers to assist spray decision making and planning.

5.1. Global positioning systems (GPS)

The use of satellite based GPS (Global Positioning Systems) for navigation may be familiar to many growers. It is now possible to purchase off the shelf GPS receivers for about \$1500. These units are able to pinpoint a persons location on the ground anywhere in the world at any time by taking a fix from satellites positioned in a 12 hour (polar) orbit 20,000km above the surface of the earth. The 24 satellite network has been placed in space and is maintained by the US Department of Defence. However anyone with a suitable receiver can freely access the system. Navigation information is obtained by determining a receiver's distance from a minimum of 4 satellites. The satellites send out a signal in which the time of transmission and the satellite's position is encoded. By knowing the time on the ground when the signal is received and the speed of the radio signal, (the speed of light), the receiver's computer is able to determine its distance from the satellite. The small GPS receivers, often not much larger than a cigar box, are also able to determine a person's speed across the ground as well as give bearings and estimated times of arrival at way points. Most units have an accuracy in the order of 100 metres.

Such units may soon be fitted to aircraft for determining the location of paddocks and maintaining flight lane separations. To increase the accuracy of the technology for this purpose, differential GPS systems have been developed which allow corrections from a fixed ground based receiver to be relayed to an agricultural aircraft in flight. These corrections transmitted by radio signal allow accuracies of 1-2 metres to be considered. Suitable computer software allows the exact track of the aircraft over the ground to be recorded and printed out on a PC when the aircraft returns to base. Should this technology become accepted in the industry, routine flagging using human markers could become a thing of the past.

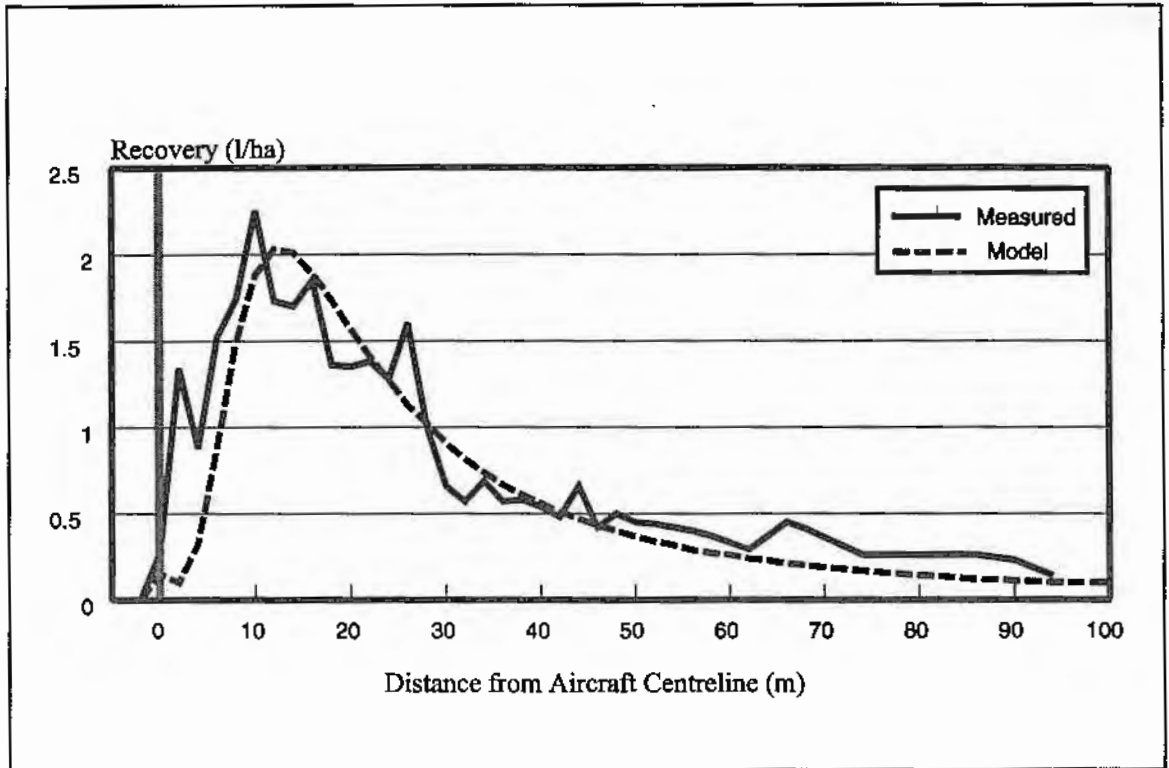
6. Research and development

The Centre for Pesticide Application & Safety, is currently undertaking a three year study to closely examine the fate of insecticides when released above the crop canopy. In particular the work is focussing on the amount of material which travels downwind away from a paddock and measuring deposit profiles in the canopy. This project, part of a much larger program investigating the fate of insecticides in the riverine environment is being jointly funded by the Land & Water Resources Research & Development Corporation, The Cotton Research & Development Corporation and the Murray Darling Basin Authority.

As an example of the type of work being conducted Figure B5-1 shows the same insecticide deposit profile shown in Figure B4-4 with a mathematical model of the deposit plotted alongside. The graph shows that the two profiles are remarkably similar. If such mathematical equations can be validated from field research it may be possible to more accurately predict the success of a spray job in advance and develop low drift strategies for the more efficient use of agricultural pesticides.

When the results of this program are finalised in 1995/96 it is hoped that guidelines for pesticide application will be published which will allow industry standards to be developed.

Figure B5-1. Comparison of top canopy coverage and mathematical simulation





SECTION B6

**Extension, information
and training**

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EXTENSION INFORMATION AND TRAINING

Introduction

A national program of accreditation workshops has been established following the success of a pilot program developed by J. Harden and staff at the University of Queensland Gatton College. The national program is delivered as a one day workshop program in Queensland and a two day workshop in New South Wales. These programs as well as those in Victoria, Tasmania, South Australia, Western Australia and the Northern Territory meet the National Core Competencies set for accreditation of successful candidates. The program is designed to provide a common base of information for users of pesticides nation-wide.

Satisfactory completion of the programs including the associated assessment leads to the accreditation of operators and the issue of an appropriate certificate. It has been determined nationally that the accreditation will be current for five years from the time of issue to successful candidates. The completion of further training during the five year period will probably be a requirement for re-accreditation and the development of training modules for specific cropping systems is underway at present.

Contact numbers for information about accreditation are as follows:

New South Wales: Mr R.I. McEvoy, RTC of NSW, telephone (02) 251 1700, fax (02) 221 6913

Queensland: Ms M. Mahon, QACAC, telephone (07) 844 7261, fax (07) 844 7307

The National Core Competencies currently being addressed in the accreditation program are:

1. Legislation

- (a) To be able to explain obligations and responsibilities in relation to relevant legislation relating to the use, storage and disposal of farm chemicals in their State (including the recognition of the label as a legal document).
- (b) Identify sources of specific information with regard to farm chemicals.

2. Label interpretation

Recognise and interpret the information on a label of a pesticide container including:

- rates of application
- safety directions on a label
- poison scheduling
- special directions

3. Safety

(a) Personal

Select, use and maintain appropriate safety and first aid equipment required for the use of farm chemicals.

(b) Environmental

Demonstrate a working knowledge of the specific requirements relating to the safe transport, handling, storage and disposal of farm chemicals and containers.

4. Application

Demonstrate a knowledge of methods available for applying pesticides including:

- controlled droplet application (CDA)
- hydraulic application
 - state the nozzle types available and select nozzles for specific jobs
- airshear
- aerosols

5. Integrated Pest Management (IPM) strategies

Discuss the principles of integrated pest management incorporating cultural, chemical, mechanical and biological control.

6. Record keeping

Draw up and demonstrate use of an appropriate farm chemical application record sheet.

7. Delivery of the Accreditation Program

In developing a program which addresses these competencies, kits of written and physical resources have been developed, trainers accredited and workshops delivered throughout production areas. It is pleasing to note that many Australian cotton growers have already undertaken and satisfactorily completed this workshop and are accredited users of pesticides.

It is anticipated that all cotton growers, and indeed, all primary producers and their staff who are involved in the storage, handling and application of pesticides will complete this basic accreditation program. It is then proposed that training in specific aspects of the safe and effective use of pesticides for particular primary industries will be provided. The cotton industry is obviously one of these industries and it is envisaged that half day training modules will be developed and available to those who have already completed the basic one day accreditation program. As a result of work already completed at the University of Queensland Gatton College by Plant Protection, the Centre for Pesticide Application & Safety (C-PAS) and the Queensland Department of Primary Industries (QDPI) staff and the current project supported by the Cotton Research and Development Corporation on the use of ground spraying equipment being carried out by QDPI and C-PAS staff, a specialist training module will be developed. This training module will be trialed and available for delivery to the industry in the future.

Specialist modules are also being developed for other production situations such as evergreen tree crops, vegetables, deciduous trees and vines, and amenity horticulture.

7.1 General comments on the Accreditation Program

The cotton industry has strongly supported the program and the comments from participants are very favourable. However, some growers consider the program to be too basic containing material they already understand. While this may be the case for some, it is important that a uniform foundation program is undertaken by all who use pesticides so that there is industry-wide understanding of the basic aspects of the safe and effective use of pesticides. In addition it is particularly important that the users put into practice the aspects of safe and effective pesticide use contained in the program. Safe storage, including locked sheds, use of properly selected and maintained respiratory and dermal protection equipment and the maintenance of spraying equipment and its proper calibration are areas requiring particular attention.

This will enable the community to be assured that registered pesticides are being used by people who have an understanding of their safe and efficient use as part of realistic plant protection activities.

8. Calibration

Many users say that they feel competent to calibrate application equipment. An analysis of the actual situation does not support this confidence. Few producers can prove they are calibrating application equipment and therefore applying the required quantity of pesticide to a target area. The maintenance of records of all aspects of each spraying job, including calibration, is also essential.

Calibration is more than a once a year or once a season examination of the machine from an output point of view. Calibration should be a once a day or twice a day checking exercise which includes an examination of all sprayer components, particularly the output of hydraulic nozzles and the operation of pressure gauges and pressure regulators.

Dedicated attention to calibration will reduce the incidence of over-dosing or under-dosing of target areas, thus reducing non-optimum use of the product as well as unnecessary contamination of the environment. Under-dosing or lower than standard output of hydraulic nozzles, can be a consequence of blocked nozzles or nozzle filters. This is difficult to detect with the eye and often goes unnoticed until a major blockage occurs. We know this leads to pest escapes and ongoing problems including a considerable waste of time and effort.

When nozzles are worn the result can be the over-dosing of sprayed areas, the waste of product and carrier and of course a significant increase in costs. We should be reminded (particularly those who have completed the training program, which is designed to highlight competency in calibration) that equipment calibration is of benefit to users and the community in both financial and environmental terms. Most users are acknowledging the importance of calibration during the training program and the need is to implement this procedure and record the information in the spray records kept for each job.

9. Use of information

The training programs and extension information available in the area of pesticide application and safety should allow producers to make informed decisions. Some of the particular aspects which then deserve detailed consideration are: who will do the pesticide application; how will it be done; what equipment will be used and under what conditions; will a contractor or a self-employed or employed person do the job. **Finally** and very importantly has the whole operation been the subject of a realistic financial appraisal which includes examination of the need to apply a pesticide as a timely and strategic plant protection input directed at economic cotton production.

On many occasions a retrospective examination of a pesticide application operation indicates that a far more cost effective system could have been used. The whole purpose of education and training in this area is to provide producers with the information to make better decisions, leading to improved profitability and enhanced environmental and user safety. If this is not happening for you then seek assistance to see that your need for information is met.

9.1 Extension and communication

In addition to the traditional sources of extension information which includes, government agencies, industry personnel, educational institutions and consultants, there is a need to be aware of the organised training activities which lead to a better understanding of pesticides and their safe use. These include half day and one day workshops, seminars and short courses of one week or longer dealing with pesticide application and safety.

Producers should carefully examine the material provided by manufacturers and/or industry in relation to its factual base and appropriateness for particular operations. Staff of the Centre for Pesticide Application & Safety and the Plant Protection Section at the University of Queensland Gatton College, government departments in both Queensland and New South Wales, consultants and industry personnel are endeavouring to provide factual information of particular use to all who apply pesticides.

10. Technical understanding

Fundamental to all aspects of the operation of application equipment, particularly that used for applying liquid formulations of pesticides distributed as droplets to the target is an understanding of droplet size. This is important to ensure effective target contact and to minimise losses out of the target area. Too much emphasis may have been placed in the past on trying to specify the particular droplet sizes for each operation. Producers may be better served by adopting small, medium and large as the droplet size categories, with small being droplets up to 150 μm ; medium being 150 to 300 μm ; and large being droplets over 300 μm . An understanding of the various types of equipment in relation to the percentage of droplets produced in these size categories is fundamental to the application of liquid formulations of pesticides to the various targets important in the cotton industry.

If this information is required in relation to selection and use of hydraulic nozzles, it emphasises the need to know about the nozzle type, wear and pressure of operation in particular that the percentage of the spray cloud as small, medium and large droplets is known. In considering airshear equipment we need to know about flow rates and air speeds in particular. For centrifugal droplet generating devices, CDA sprayers, we need to know about the disc and/or cage type, rotational speeds and flow rates. For each of

the types of droplet generating equipment and the varying target requirements in relation to both pests and products, producers must be aware of the droplet sizes required and how that will influence the final result. Information on this topic is included in various extension and workshop publications and increasingly being supplied by machine manufacturers.

All extension and communication activities should be firmly based on the factual information available today. It must be understood and communicated to all involved in making application of pesticides an effective plant protection activity. Industry must be asked for and supply information about the equipment they supply, to ensure that informed pesticide application decisions can be made. The manufacturers of both pesticides and biologicals, should be encouraged to provide clear information on product application, including information on labels in the future. They should provide information on rates of use which relate to target areas to support use of the different types of application equipment available to the industry.

11. Additional training & information

Agsafe Ltd has established a comprehensive program of education and assessment for the staff of manufacturers and resellers of pesticides. This has been extended to include a program for the accreditation of product manufacturer and reseller premises. This training and accreditation is available to users of pesticides if required. As the result of the Agsafe Ltd accreditation program a comprehensive set of written information is available and pesticide users may find the publication 'Farm Chemicals Manual: A Guide to Safe Use and Handling' available from Agsafe Ltd particularly useful.

Contact number for Agsafe Ltd: (02) 925 0711

Further Reading

Industry, government and other authors have published a number of useful publications including:

Banks, A., Broadley, R. H., Collinge, M. and Middleton, K., 1990, Pesticide Application Manual, 2nd ed., published by QDPI.

Ciba-Geigy Staff (Agricultural Division), Application Techniques for Plant Protection in Field Crops, 2nd ed.

Hughes, P., Rickman, J. and Marshall, J., 1994, Pesticide Application Guidelines, published by QDPI.

Matthews, G.A., 1993, Pesticide Application Method, 2nd ed., Longman.



INDEX

- accidental spills, 41
 accreditation program, 101
 active ingredient, 29
 adjuvants, 77
 aerial application, 83
 agitation, 76
 air assisted boom, 15
 air movement, 67
 air shear boom, 11, 14
 air-assisted sprayers, 11
 air-conditioned cabs, 32
 aircraft operating conditions, 87
 aircraft types, 81
 analytical techniques, 57
 anemometer, 70
 application, 100
 application windows, 91
 aqueous solutions, 74
 bio-degradation, 39
 bio-formulations, 75
 biological buffer zones, 93
 biologicals, 33
 Blood tests, 33
 buffer zones, 35
 buffering agents, 77
 bureau of Meteorology, 70
 calcium and magnesium salts, 76
 calibration, 17, 101
 calm conditions, 70
 carbamates, 33
 carrier, 29
 catch efficiency, 52
 CDA boom, 11, 14
 check valves, 16
 chemical, 39
 chemical fate, 39
 chitin, 33
 clothing, 32
 communication, 37
 compatibility, 77
 containers
 empty, 45
 rinse, 44
 crop absorption and harvest, 39
 crop conditioners, 23
 dealing with spills, 42
 degradation, 39
 delta T, 69
 disposal, 41
 disposal site, 42
 drift, 67
 drift control, 93
 droplet
 measurement, 56
 recovery, 56
 droplet capture, 52
 droplet generation, 49
 droplet size, 54
 canopy penetration, 9
 coverage, 10
 drift potential, 10
 evaporation risk, 9
 gravity effects, 10
 wind turbulence, 10
 droplet transmission, 51
 emulsifiable concentrates, 75
 environment, 38
 extended flight lane separations, 87
 extension and communication, 102
 face and eyes, 32
 filters, 15
 fluorometric analysis, 58
 formulation, 29
 formulations, 73
 global positioning systems (GPS), 94
 gloves and boots, 32
 granules, 75
 groundwater movement, 39
 handling and storage, 32
 herbicide application, 21
 herbicide formulations, 74
 horizontal wind speed, 63
 hydraulic boom, 11
 droplet size, 11
 hydraulic booms
 droplet size, 12
 even fan, 13
 flat or tapered fan, 13
 hollow cones, 12
 L.P., 14
 low drift nozzles, 14
 nozzles, 12
 overlap, 13
 solid cones, 12
 spray angle, 12
 spray swath, 13
 image analysis, 59
 INFOFAX, 70
 insecticide formulations, 75
 insecticides, 23
 insects, 3
 integrated pest management, 100
 inversion layer, 70
 inversions, 36
 katabatic winds, 66
 label, 76
 label interpretation, 99
 laser techniques, 58
 leaching, 39
 legislation, 99
 liquid concentrates, 74
 markers, 16

- marking, 92
- micrometre, 54
- Micronair AU5000, 56, 82
- mixing, 76
- mixing the pesticide, 32
- monitoring exposure, 33
- MSDS, 31, 33
- mud map, 37
- native flora
 - spray drift, 38
- NMD, 54
- organo-chlorines, 33
- organophos-phates, 33
- people management and safety, 33
- personal protective equipment, 32
- pesticide label, 31
- pesticides
 - definition, 29
 - placement spraying, 83, 84
 - poison schedule, 31
 - poison warning, 31
 - poisoning, 30
 - pressure gauges, 15
 - protection, 30
 - pyrethroids, 33
 - record keeping, 100
 - records, 37
 - reducing spray drift, 35
 - relative humidity, 69
 - research and development, 94
 - respirators, 32
 - run-off and erosion, 39
 - S5, 31
 - S6, 31
 - S7, 31
 - safe application
 - pesticides, 34
 - safe handling, 30
 - safety, 100
 - shut-off valves, 16
 - smoke, 70
 - soluble powder, 75
 - span, relative, 55
 - spray drift, 34
 - spray sure, 43
 - stability ratio (SR), 67
 - sulphate of ammonia, 77
 - surfactant, 29
 - suspension concentrates, 74
 - synergists, 33
 - temperature, 68
 - temperature and humidity, 36
 - testing for water quality, 76
 - thermal movement, 66
 - thunderstorms, 66
 - turbulence, 65
- ULV, 75
- urine tests, 33
- vertical air movement, 66
- VMD, 54
- volatilisation, 39
- water acidity/alkalinity, 76
- water and oil sensitive paper, 57
- water clarity, 76
- water dispersable granules, 74
- water quality, 76
- weather conditions, 35, 70
- weeds, 3
- wettable powders, 74
- wetting agents, 77
- whirling psychrometer, 69, 70
- wide swath (ULV) spraying, 85
- wide swath spraying, 83
- wind, 35, 39
- wind gradient, 65
- wind speed, 35

