SPRAYING AGRICULTURAL CHEMICALS

By Simon White & Peter Hughes, QDPI

KEY POINTS:

- **Set up the sprayer for good coverage**
- **Match the droplet size (or spray quality) and spray volume to the product requirements**
- **Avoid still conditions when spraying**
- **Avoid high temperatures when spraying**
- **Fan nozzles outperform hollow cones for applying insecticides**

To maximise spraying efficiency, pesticides must be applied at the minimum pesticide rate which will produce effective pest management without wastage through off target effects such as run-off or drift.

For this to occur, a sprayer must be capable of:

- Producing sufficient droplets of the correct size.
- Depositing these droplets in sufficient numbers evenly over the target
- Minimising effects off target.

Crops, pastures, people, stock and water supplies can all be affected by spraydrift. The resulting pollution, crop damage and the potential health hazards are something that is no longer environmentally acceptable.

APPLICATION BASICS

Droplet size

Droplet size depends on the type of equipment used and how it is set up.

Nozzles are classified by the British Crop Protection Council (BCPC) according to the type of droplet spectrum they produce. These classifications are included in most nozzle catalogues and are a useful guide for assessing the drift potential and suitability of a nozzle for a given spray job.

BCPC Category		**Approximate VMD* Range**
VF	Very Fine	< 150 µm**
F	Fine	150 – 250 µm
M	Medium	250 – 350 µm
C	Coarse	350 – 450 µm
VC	Very Coarse	450 – 550 µm
EC	Extremely Coarse	> 550 µm

µm = microns

BCPC Spray Classification

The BCPC classification system uses a set of reference nozzles to compare the spray quality of a manufacturer's nozzles. From the reference nozzles a series of curves are drawn up, if the spray quality of the manufacturers nozzle falls within the boundaries of two curves, that is the spray classification it is given. (VMD = Volume Median Diameter).

Droplet Sizes for Different Targets

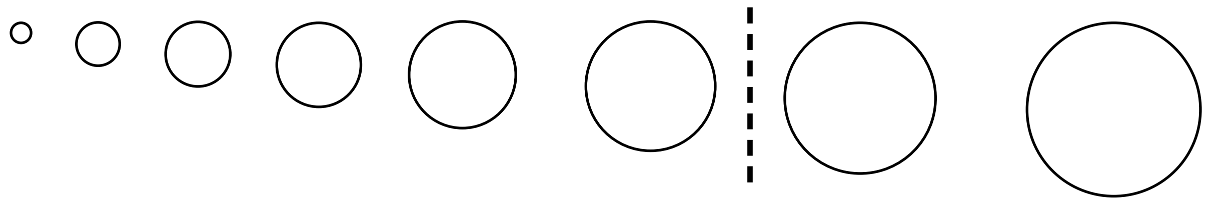
Regardless of the target our aim should be to get the best coverage possible of that target, while minimising the off-target losses as much as we practically can.

Our understanding of the droplet sizes required for different targets is slowly improving. Recommendations for the application of different product types onto different targets are emerging all the time so it is important to monitor this progress closely.

Where present we must follow label instructions as to the application of particular product types. Where this information is not provided we can apply the following 'best bet' principles.

The size of the droplet will determine its characteristics and how it will behave once released from the sprayer (**Table 1**).

Figure 20: Volume Median Diameter (VMD*) is the droplet size at which 50% of the spray volume exists in droplets larger than this size and 50% of the volume exists in droplets smaller than this size.

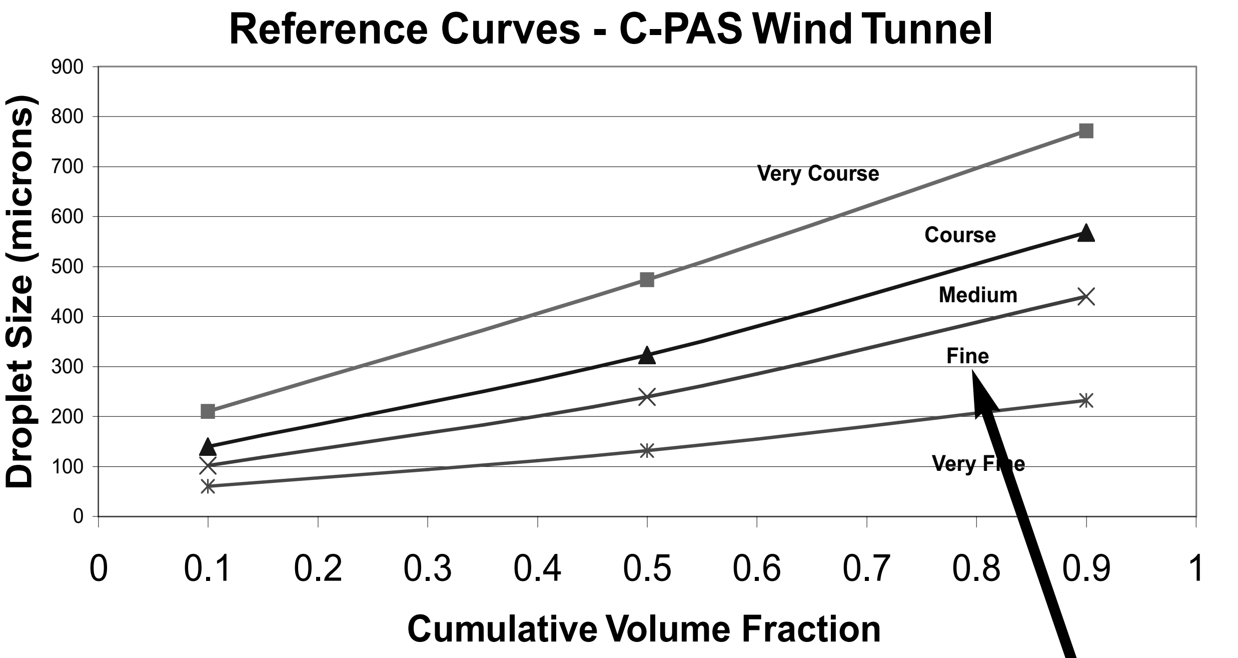


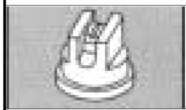
VMD

Note: The VMD is NOT the average, there will always be a greater number of small droplets than large ones.

Microns (µm) is the abbreviation for micrometers. There are 1000 microns in 1 millimetre.**

Figure 21 & 22: Example of BCPC Reference Chart and how the reference curves are used for nozzle droplet classifications tables.



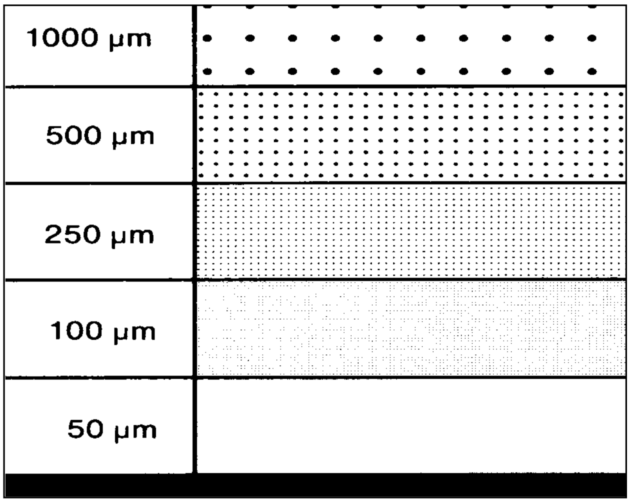
DG TeeJet® (DG)					
	bar				
	2	2.5	3	3.5	4
DG80015	M	M	M	F	F
DG8002	C	M	M	M	M
DG8003	C	C	M	M	M
DG8004	C	C	C	C	M
DG8005	C	C	C	C	C
DG110015	M	F	F	F	F
DG11002	M	M	M	M	M
DG11003	C	M	M	M	M
DG11004	C	C	M	M	M
DG11005	C	C	C	M	M

A nozzle that has been assigned a FINE (F) spray quality will produce droplet sizes within a particular range.

Spray quality:
C -Course
M -Medium
F -Fine

	Spray Classification	**Comment**
Insecticides		
Contact	Fine – Medium	If using medium stay at the finer end.
Systemic	Fine – Medium	If using medium stay at the finer end.
Fungicides		
Protectant	Very Fine	Be aware of droplet spectrum and evaporation.
Curative	Very Fine-Medium	If using medium stay at the finer end.
Herbicides		
Soil Applied	Coarse	Use appropriate water volumes to ensure coverage.
Contact	Medium	Use at the coarse end & monitor conditions.
Systemic	Medium-Coarse	Medium preferred where conditions allow.

Figure 23: Comparative Droplet Sizes (Source Agrevo & Spraying Systems)



Drift Potential

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

Canopy penetration

Coverage throughout the canopy and underneath leaves is best achieved by fine droplets. Large droplets move downwards due to gravity and will generally be deposited on horizontal surfaces and the upper most outside parts of the plant canopy.

Evaporation risk

Fine droplets will evaporate rapidly under hot dry conditions.

Table 38: Droplet characteristics.

	Droplet size groups (BCPC)		
	V. fine	Fine -Med.	Coarse+
Size	<150 µm	150 - 350 µm	> 350 µm
Canopy penetration	High	Medium	Low
Evaporation risk	High	Medium	Low
Drift potential	High	Medium	Low
Coverage / volume	High	Medium	Low
Inertia /gravity effect	Low	Medium	High
Uses	Insecticides. Fungicides.	Insecticides. Contact herbicides.	Insecticides. Soil applied pesticides.

KEY:

- Best option for most situations
- Suitable option caution recommended
- This option not recommended

Table 39: Droplet survival times and distance fallen by a spherical water droplet under different Δt's before the droplets disappear. (Δt is the difference between the wet and dry bulb temperatures).

Droplet diameter (µm)	ΔT (°C) Difference between wet and dry bulb temperatures			
	6	8	10	12
	Droplet survival times (seconds)			
10	0.2	0.2	0.1	0.1
20	0.8	0.6	0.5	0.4
50	5.2	3.9	3	3
100	21	16	13	10
200	83	63	50	42
500	333	250	200	467

Droplet diameter (µm)	ΔT (°C) Difference between wet and dry bulb temperatures			
	6	8	10	12
	Distance fallen before a droplet disappears (cm)			
10	0.03	0.02	0.02	0.02
20	0.5	0.4	0.3	0.3
50	20	15	12	10
100	313	234	188	156
200	5 000	3 750	3 000	2 500
500	80 000	60 000	48 000	40 000

Coverage /volume

As the droplet size decreases many more droplets are produced from the same volume of spray. There is an eight fold relationship between droplet size and number. As you can see in **Table 40**, you need eight times the number of 200µm droplets to have the same volume of 400µm droplets.

When using large droplets the spray volume must be increased to maintain acceptable coverage/droplet number.

The droplet density required may vary with the type of product to be used. Traditionally 20 to 30 droplets/cm^2 was considered sufficient for most products. However many products now specify on the label a droplet density of between 60 – 70 droplets/cm^2. It is also likely that with the new ingestive active products becoming available, greater coverage will be required to ensure adequate levels of control.

Inertia/gravity effect

The higher the inertia of a droplet the more likely the droplet will be deposited on the target. Large droplets have inertia due their size. The movement of large droplets is predominantly determined by gravity. Most will deposit on flat surfaces, on the ground or the outside of the plant canopy.

Small droplets have very low inertia due to their small size. To increase inertia of a droplet, increase its travel speed (air assisted sprayers use this principle). If the speed is too high too much spray will be deposited on the outside of the plant canopy, or be wasted due to droplet bounce.

Table 40: Comparative droplet numbers for different droplet size.

Size	No. of droplets/mL of spray
100µm	1909559
200µm	238732
400µm	29841

Table 41: Droplet densities for the pesticides.

Product	No. of droplets/cm2
Insecticide:	60-100
Herbicide:	
pre-emergent	20-30
post-emergent	30-40
Fungicides:	
Contact	50-70
Systemic	20-30

Application efficiency

There are many methods of assessing the efficiency of pesticide spray application. Biological assessment for insecticide application, quickly answers the question "did the spray work or not?" By measuring droplet deposition on the target surface and combining this with a biological assessment, it is possible to quickly isolate problems into either the chemical or its application. Droplet deposition can be measured using fluorescent dye tracers or with oil or water sensitive papers.

NOZZLE IDENTIFICATION

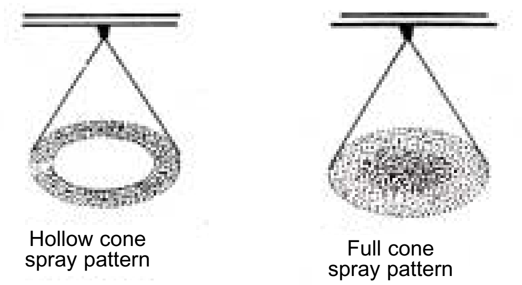
The nozzle is the most important but often most neglected and least understood component of the sprayer.

The type of nozzle selected determines the droplet spectrum produced, the volume of spray applied, the required boom height and the life of the nozzle. Each nozzle is normally identified by letters and numbers on the body of the nozzle plus a colour coding system which designates performance characteristics.

Nozzle Types

The most commonly used nozzle types in broadacre farming are cones and flat fans.

Cone Nozzles



Hollow cone nozzles are used mainly for insecticide and fungicide application. They can be operated as a broadacre spray or as a row crop spray using 1-5 nozzles for each row.

The hollow cone pattern is produced by the swirling action within the nozzle. The liquid is forced into a swirl chamber through slots in a swirl plate. The liquid then passes through the orifice and forms a thin sheet in the hollow cone pattern. Droplet size is smaller due to the higher energy in the liquid sheet.

Full or solid cone nozzles give a coverage across the full area of the cone. They are used for soil applied herbicides and situations where high volumes are required.

Characteristics of cone nozzles:

To decrease spray angle:	decrease orifice size decrease swirl slots decrease swirl chamber depth increase pressure
To decrease droplet size:	decrease orifice size decrease swirl slots decrease swirl chamber depth increase pressure

Fan Nozzles

With fan nozzles liquid is forced into the nozzle chamber and through a rectangular or lens shaped orifice.

There are two main types of fan nozzle:

Even Fan Nozzle:

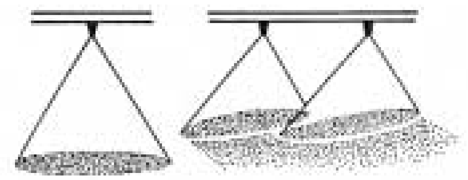
Even fan
spray pattern

The even fan produces an even distribution pattern across the full nozzle swath width.

They are used for band application of herbicides. The nozzle fan angle and operation height determines the width of the band.

All brands carry the letter E on the face of the nozzle so as they can be easily identified.

Flat or Taper Fan:



Taper fan
spray pattern

Taper fan showing
nozzle arrangement

Flat or tapered fan nozzles are the most common type of nozzles used in broadacre situations and increasingly for insecticide application in cotton. They are characterised by an individual elliptical spray pattern. Uniform distribution is achieved by a 30% overlap of the tapered edges of the spray pattern.

Striping due to boom height variation can be minimised by doubling the boom height to achieve double coverage.

At very lower pressures the variation of spray under the boom increases due to the decrease in the fan angle of the nozzle.

Table 42: Flat fan nozzle heights (above the target) at 50cm nozzle spacing.

Fan Angle	Single Coverage	Double Coverage
80^{o}	46cm	92cm
110^{o}	25cm	50cm

Flood Nozzles

Flood nozzles are high volume, low pressure, wide angled fan nozzles. These nozzles are used for pre-plant incorporated and surface applied herbicides. Because this nozzle has a large orifice it may be used in situations where clogging is a problem such as liquid fertiliser application.

Low Drift (Drift Guard) Nozzles:

The low drift nozzles operate at conventional pressure but have a different design. They have a pre-orifice plate above the nozzle chamber which cause the nozzle to produce more large droplets and less of the small droplets that may drift.

Remember: When large droplets are used to reduce drift - higher spray volumes are needed to maintain acceptable coverage.

Air Induction Nozzles

These nozzles use a combination of hydraulic nozzle and air inclusion to produce droplets. The two main types of nozzle are those that use venturi air aspiration (eg TeeJet® AI, Hardi® Injet, Turbodrop®) and those that use an air compressor for the air aspiration (eg TeeJet® AirJet and the Airtec®). The droplets produced by the nozzles are a mixture of air and water. This air inclusion depends on the properties of the pesticide formulation and any additives included in the mix.

Cones vs Fans

There are a number of situations where a choice is made between a hollow cone and flat fan. The main differences between the two nozzles are:

¥ Cones produce more droplets less than 100µm (drift & evaporation prone)

¥ Droplets from the cone float more because they have a lower velocity when exiting the nozzle

¥ Cones have a spray angle of 80^{o}, whereas flat fans are available in 110^{o}.

Figure 24: Single Coverage Spray Pattern.

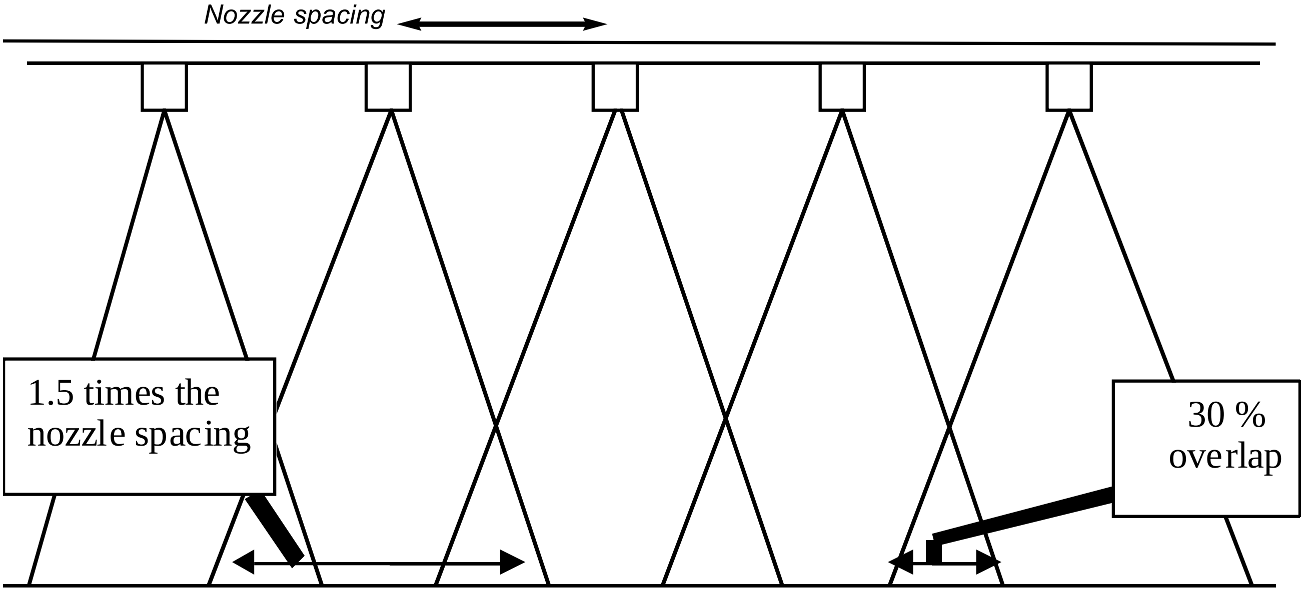
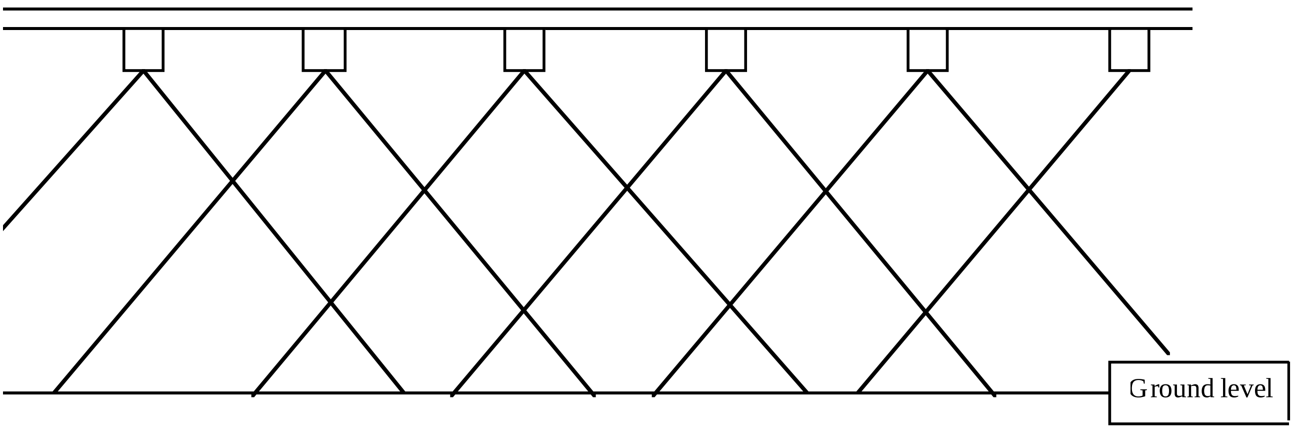


Figure 25: Double Coverage Spray Pattern.



Other nozzles are available for specific applications such as off centre depositions, twin outlets, deflector, agitation, boom ends and rinsing. Check identification against manufacturers specifications.

MATERIAL OF CONSTRUCTION

Nozzles are made from a wide range of materials and the material of construction is normally depicted by letters and colours.

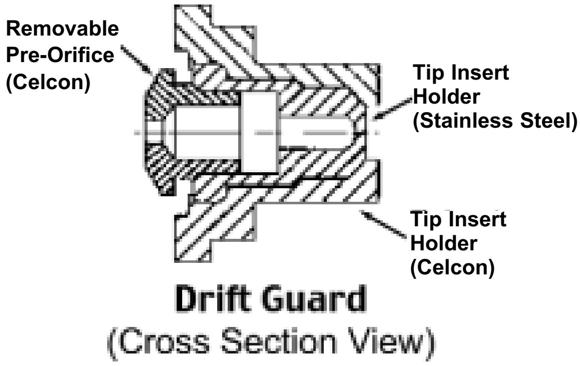
For example:

Spraying systems
- **VK - ceramic**
- **VH - hardened stainless steel**
- **VS - stainless steel**
- **VP - polymer**
- **VB - brass**

Ceramic nozzles are best value for money. Although they cost more initially, they are the most resistant to wear.

ALL NOZZLES WEAR AND NEED TO BE REPLACED ONCE THEIR FLOW RATE EXCEEEDS 10% MORE THAN MANUFACTURERS SPECIFICATIONS.

Figure 26: Teejet - Drift guard Nozzle (Source: Teejet®)



COLOUR CODING

"OLD" MANUFACTURER IDENTIFICATION SYSTEM

The old systems used numbers, letters and colours combined to give a full identification for each manufacturers product. Confusion arose because each manufacturer combined identifying characters in different combinations. If in doubt consult manufactures catalogues/ literature.

"NEW" ISO STANDARD COLOUR CODING FOR FLOWRATES.

A recent innovation for coding of nozzles is the ISO standards for colour coding and flowrates for nozzle.

Manufacturers using ISO standards all use the same colour codes for nozzles with the same flowrates. So a Hardi 110 - 02 fan (yellow) can be replaced with a TeeJet 110 - 02 fan, which also is yellow, or a Yellow Lurmark 110 fan.

ISO coding allows easy identification of flow rate. Most companies are now depicting their nozzles flow rate through a numerical system as well as a colour coding system. Whilst each number and colour should be checked against the manufacturers specification, with USA designed nozzles the number represented is normally 10% of the flow rate in US gallons/min (TeeJet 02, Delevan 2, Lurmark 02 = 0.2 US gallons/minute at 40psi).

WATER QUALITY

The quality of the water used can adversely affect a herbicide's performance. Ideally water should be clear, colourless, odourless and neutral in pH. When available, rain water is the best bet. If water contains excessive solids obvious problems such as nozzle blockages will occur. Less obvious will be the binding of the chemical to the suspended materials and subsequent loss in its effectiveness. The effectiveness of some chemicals can be drastically reduced by suspended clay particles. As well, solids accelerate nozzle wear.

IF A COIN CAN NOT BE SEEN IN THE BOTTOM OF A BUCKET OF WATER IT IS TOO DIRTY TO USE FOR SPRAYING.

Water which is either acid or alkaline in pH may break down or hydrolyse specific chemicals. If the water is known to be alkaline, spraying should commence immediately after mixing. Water high in calcium or magnesium salts (hard water) may also cause problems with mixing as the stability of suspensions and emulsions is reduced.

A quick guide to the suitability of water for spray applications can be obtained using the following procedure:

1. Make up 500mL of correctly diluted spray in a clear glass sealed container according to the manufacturer's instructions.
2. Mix thoroughly.
3. Allow to stand for 30 minutes. If, after this time, creaming, sedimentation or separation into layers occurs, the water may be unsuitable for mixing sprays. If suspected of being unsuitable, a sample of this water should be chemically analysed for salt and hardness levels.

Different brands of the same chemical may react differently because of different additives in each formulation.

If poor quality water has to be used, spray immediately after mixing, ensure adequate agitation is occurring in the tank and reduce the total water volume if at all possible.

Calibration

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

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

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

Preliminary measurements

A. Nozzle output (L/min)

- Check the pressure drop between the nozzle and the pressure gauge on the controls.

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

Total spray boom output(L/min) = Sum of all individual nozzle outputs (L/min).

B. Operating speed (km/h)

- For tractors and groundrigs that are fitted with ground speed sensors, check equipment calibration under field conditions. Refer to the manufacturer's operating manual.
- For tractors and groundrigs that are not fitted with ground sensors:

  Measure out 100m in the field to be sprayed. Select the gear and RPM for comfortable operation and measure the time taken to cover the 100m that has been marked out. Do a couple of runs and average the times.

Operating speed (km/h) = Distance travelled (m) ÷ Time taken (sec) x 3.6.

Note: 3.6 is the factor that converts m/sec to kph.

C. Effective sprayer width (m)

Broadcast application:
Nozzle spacing (m) x Number of nozzles.

Row application:
Row width (m) x Number of rows being sprayed.

Band application:
Band width(m) x Number of rows being sprayed.

Table 43: Approximate band widths for different crop heights (1m rows).

Crop height (m)	Band width (m)
.10	.30
.15	.30
.30	.40
.40	.50
.60	.75
.80	.90
.90	.95
1.00	1.00

Spray calculations

1. Application volume (L/ha sprayed):

Note: Label directions refer to the volume applied per sprayed area. This formula calculates application volume per sprayed hectare.

Application volume (L/ha sprayed) = Total boom output (L/min) x 600 ÷ Tractor speed (km/h) ÷ Effective width (m)

Note: 600 is the factor that converts L / min to L / hr and kph x m to Ha / hr.

2. Flow rate for a known application volume (L/min):

Output (L/min) = Application volume (L/ha sprayed) ÷ 600 x Speed (km/h) x Effective width (m).

3. Amount of product to be added to the spray tank:

Amount (L or Kg) =Spray tank volume (L) ÷ Application volume (L/ha) x Product label rate (L/ha or Kg/ha).

4. Band / Paddock ratio:

Band / Paddock ratio = Band width (m) x No. of rows ÷ Sprayer swath width (m)

Solid planting (1m rows):
Sprayer swath = Number of rows x 1.0 (m)

Single skip planting (1m rows):
Sprayer swath = Number of rows x 1.5 (m)

Double skip planting (1m rows):
Sprayer swath = Number of rows x 2.0 (m)

If using tramline or irregular row widths, measure the distance from the centre of one spray run to the centre of the next spray run.

5. Amount of product required for the paddock area:

Product (L or Kg) = Paddock size (Ha) x Product rate (L/ha or Kg/ha) x Band/Paddock ratio.

6. Paddock area (Ha) that can be completed with each full spray tank:

Paddock hectares / tank = Tank size (L) ÷ Application rate (L/ha sprayed) ÷ Band /Paddock ratio.

7. Sprayer output per paddock hectare:

Output (L/ha paddock) = Application rate (L/ha sprayed) x Band / paddock ratio.

Suitable Conditions for Applying Pesticides

Environmental conditions have a large influence on how much of the product we spray actually reaches the target. Considerable losses of chemical can occur when spraying under adverse environmental conditions. The two major losses that occur are from drift and evaporation before the spray reaches the target.

Spraying in unsuitable conditions

When spraying in unsuitable conditions you are not only wasting money from wasted product, but you may also be reducing efficacy and therefore respray interval, as well as adding to possible resistance from delivery of sub-lethal doses to the target. Damage and/or contamination to sensitive areas, crops and pastures are also of major concern when drift is present.

Monitoring

Monitoring of conditions before and during a spray job is essential to ensure you are aware of changes in conditions as they occur. You must be able to record and keep a hard copy of weather condition data. Data may be obtained from a stationary weather station or from hand held equipment. Hand held weather equipment is advised to enable conditions at site of application to be monitored. It is suggested each time you refill that you check conditions. A good operator will be aware of changing conditions when spraying and take necessary action.

Most susceptible set-ups for environmental loses

Droplets under 250 microns (0.25mm diameter), classified in the Very Fine and Fine categories of the British Crop Protection Council (BCPC) specifications are the most susceptible to drift and evaporation. For this reason extra care should be take when spraying by ground and air with set-ups that are classified in these categories.

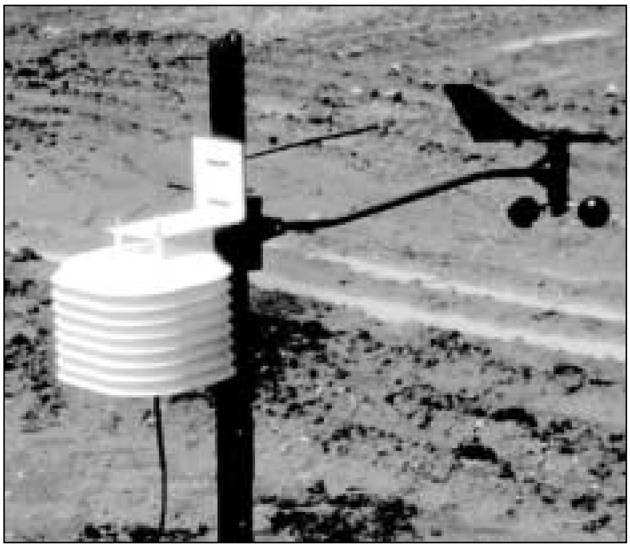


Figure 27: Stationary in-the-field weather station.

Wind Speed: 1 to 4.2m/sec (3kph to 15kph)

Some wind is needed to be present to ensure penetration into the crop and to prevent stratification of air layers (further discussed later). Wind less than 3kph is generally unpredictable in direction. High wind conditions can cause increased downwind drift potential. Always be aware of the wind direction and what areas/crops are downwind from where you are spraying. All spray aircraft should be fitted with on-board exhaust 'smokers' for determination of prevailing wind direction. They may also be used to indicate relative strength of the wind and to some extent the amount of turbulence or inversions present. To assist in aerial application growers or ground crew can light bonfires so the smoke can show prevailing winds and further assess the suitability of conditions to spray. A wet bale of hay burns slowly and creates a visible white smoke for assessing conditions.

Spraying under calm, high or variable wind conditions is not recommended.

Temperature:

Morning: Up to 29°C

It has been shown that once temperatures have risen above 29°C significant losses in spray can occur before spray deposits reach the target.

Afternoon: Below 32°C and as long as the ground temperature is cooler than the air temperature.

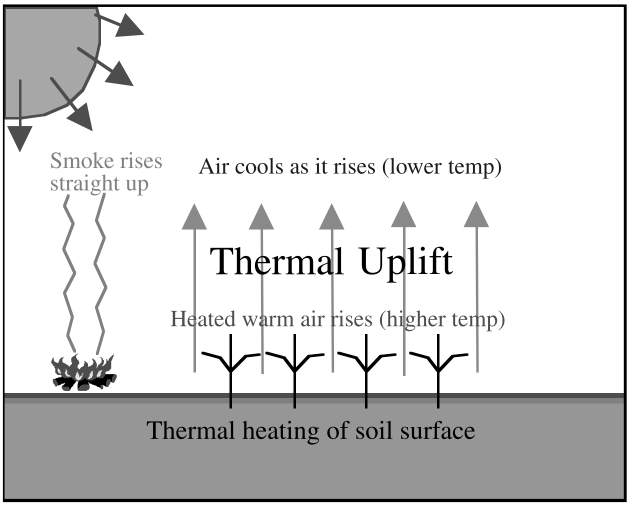
If the ground temperature is hotter than the air temperature which has begun to cool in the late afternoon it is probable that thermal uplift is occurring and therefore conditions are not suitable for spraying.

Thermal Uplift:

NO spraying should occur during thermal uplift

Thermal uplift is when the hot ground heats the air near it and the hot air rises. Under thermal uplift it is harder for droplets to fall (against the rise of air), hence droplets may be carried up instead of falling and evaporate or drift off target.

Figure 28: Air movement in Thermal Uplift.



Thermal activity can be detected by measuring a higher ground air temperature than the air temperature above the crop. Smoke can be used as an indicator, which will continue to rise as the hot air rises.

Relative Humidity:
Relative humidity is a measure of moisture in the atmosphere expressed as a percentage of the total amount of moisture (saturation) which the air can hold at a given temperature.

As relative humidity increases the potential for evaporation decreases as the air becomes saturated with moisture. When relative humidity is low, water based sprays can evaporate quickly and product can be lost. In general, spray when the relative humidity is high (that is when the difference between wet and dry bulb temperatures is less than 10°C (see **Table 44**, next page)).

Inversions & Cold Air Drainage:

NO spraying should be carried out under an inversion or cold air drainage.

Inversions are when there are two air masses present of differing temperature, which do not mix. They are common on nights with limited cloud cover and light to no wind. Sprays released above an inversion may not reach the target due to the unmixed layers of air. Sprays released below an inversion remain concentrated and if drift occurs, concentrated levels of chemical may move off target and cause damage.

Inversions can be identified with smoke indicators when smoke will layer and move laterally in a concentrated cloud. If the spray from ground or aerial application tends to hang above a crop it is likely there is an inversion present and you should stop spraying until conditions become favourable.

Cold Air Drainage

Air acts as a liquid and as it cools it falls and drains to the lowest point, this is known as cold air drainage. It is most common in the late afternoon/evening when sometimes you can feel the cooler air moving in. It is important to consider possible cold air drainage when you are spraying. The low point which the air drains to could be in the same paddock, a neighbouring gully or another crop on lower ground. Smoke indicators may visually indicate if this is occurring. Cold air drainage can be responsible for off target loses and damage to sensitive areas.

For more information refer SprayPAK.

Figure 29: An inversion layer.

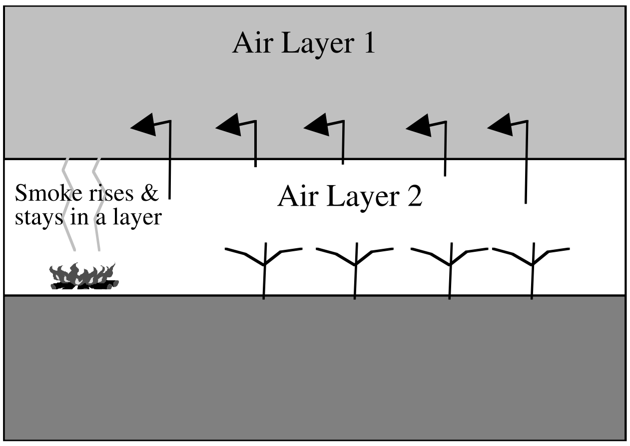


Table 44: Temperature and humidity levels for optimum spraying conditions. The Stop & Go spray chart.

	Temperature (ºC)								
RH (%)	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0
100	Application is not recommended due to the risk of rainfall and loss of pesticide.								
90									
80									
70									
60									
50									
40									
30									
20									
10									
Note: This is a guide only. All weather parameters and spraying operations must be monitored during spray operations, and BMP (PAMP) guidelines followed.									

	Best option for most situations
	Suitable option for spray application but caution recommended
	This option is not recommended