Shields Ain't Shields

A CRDC Funded Shielded Sprayer Study – 2002/03 Field and Laboratory Trial Results

Conservation Farmers Inc. (CFI)
The Centre for Pesticide Application and Safety (CPAS)

www.aghort.uq.edu.au/cpas www.cfi.org.au www.crdc.com.au

1. SHIELDS AIN'T SHIELDS

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Ask GB, Agricultural Spraying Kare P/L (phone 07 4613 4220)

Study Program

The study evaluated 5 tractor trials in NSW and Queensland considering the effect of nozzle selection (spray quality), water volume, travel speed, meteorological impacts and shield architecture on crop safety (measuring either yield and/or leakage) and herbicide efficacy. Additional information on meteorological conditions and spray quality classification are included to further extend the spray application knowledge base of applicators. This booklet is divided into six sections; **Page #**

Background

Shielded sprayers have been widely and quickly adopted by cotton growers for weed control in the inter-row. In the last three seasons, the increase in area sown to RoundUp Ready® cotton has been a major contributor to this because the label directions of RoundUp Ready Herbicide® specifys the use of shielded sprayers when growing RoundUp Ready® cotton.

After the 2001/02 season, growers reported yield losses up to 30% after using shielded sprayers. It is thought that leakage of spray was the probable cause of this yield loss. The Cotton Research and Development Corporation (CRDC) provided funding to both Conservation Farmers Inc (CFI) and The Centre for Pesticide Application and Safety (CPAS), School of Agronomy and Horticulture, The University of Queensland, Gatton Campus to undertake studies to determine the major factors causing herbicide leakage from shields and to develop strategies that would reduce potential yield loss, but not affect weed control.

Both CFI and CPAS have collaborated in a number of trials to maximise resources. This document highlights preliminary wind tunnel (laboratory) and field research on the influence of shield height, wind speed (travel speed), nozzle selection (spray quality), boll retention and herbicide efficacy. In a one year study there is no scope to confirm experimental observations, and therefore **all results should be seen as preliminary outcomes**.

Conservation Farmers Inc. conducted five field trials (three in Moree, one in Brookstead, one in Oakey). CPAS collaborated with two trials in Moree and one trial in Brookstead and conducted the low speed wind tunnel assessments. CPAS conducted a further two shielded sprayer and two conventional boom groundrig trials, which are not reported in this booklet.

Synopsis

- Leakage from shields is reduced by using coarser droplets (a VERY COARSE rather than FINE or MEDIUM spray quality).
- Using coarser spray qualities may affect coverage and efficacy at low application volumes
- Increasing travel speed increases the risk of leakage and subsequent crop damage
- Increasing shield height above 5 cm dramatically increases leakage
- Spraying into a strong headwind increases the risk of leakage (as net wind speed is additive of the wind and travel speeds) and subsequent crop damage
- Consider increasing water volume in dry conditions to maintain herbicide efficacy (noting application volume label limits)
- Crop yield and the control of weeds has been shown to vary by changing spray quality from FINE/MEDIUM to VERY COARSE.
- It was often noted that greater influences to leakage were made by changes to the setup and operation of the shield, rather than any one shield consistently outperforming another shield.

Acknowledgements

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- John Rochecouste (MaurRoche Agriculture P/L)
- Graham Betts (Ask G.B. Agricultural Spraying Kare P/L)
- Bill Gordon (Bill Gordon Consulting)
- Tony Bailey (“Woodstock”, Milo Farms Moree)
- Justin Ramsay (“Midkin”, Auscott Ashley)
- Geoff Dunlop (TAFE, Moree)
- Peter Keeley ("Warrabrook", Brookstead), and
- Doug Gordon (“Kinross”, Oakey)

Booklet compiled by Jamie Nicholls, Gary Dorr and Nicholas Woods, CPAS; Michael Burgis, CFI; and John Rochecouste, MaurRoche Agriculture P/L.

2. CFI EFFICACY TRIALS - FIELD RESULTS (NOZZLE TRIALS)

The major factors that cause leakage of spray from shields are;

(1) Spray quality; the production of fine droplets
(2) Air movement in and around the local environment of the shield (wind speed and travel speed), and
(3) Shield height above the ground

The production of FINE to MEDIUM droplets is a function of nozzle choice and pressure. This spray quality classification is normally recommended for translocated herbicides (systemic) with low application volumes (a coverage and efficacy issue may become apparent as spray quality becomes coarser on some weeds). Air movement is a combination of ground speed and wind conditions.

Reducing fine droplets decreased leakage, but reduced coverage and affected herbicide performance on the more difficult to control weeds. Increasing water volume improved herbicide performance in hot dry conditions, but excessive water volume could exceed label recommendations (and provide too dilute a herbicide concentration to the target weed).

Data from the field trials shown in Tables 1-5 highlight experimental experiences so far. The results indicate that reducing leakage is going to be a trade-off between the risk of inadequate weed control and crop safety depending upon spraying conditions. Factors to consider include;

(1) Minimising the gap between the shield edges and the ground
(2) Weather; Wind (speed, direction), temperature and Delta T (ΔT)
(3) Appropriate nozzle pressure to suit conditions
(4) Adjust speed to match conditions

Nozzle	DG95015E	
Nozzle number & pressure	**3** @ 2bar	**2** @ 2 bar
Water volume (L/ha)	**96**	**72**
Shield type	Polumbo	
Tractor speed (km/hr)	9.8	
Wind speed (km/hr)	Cross wind 9.1	Cross wind 4.6
Leakage factor	**1.0**	**0.62**
Delta T (°C)	10.2	13.2
Herbicide efficacy (glyphosate)	**Peachvine 80%**, Bladder Ketmia 100%, Nagoora Burr 100%	**Peachvine 58%**, Bladder Ketmia 100%, Nagoora Burr 100%
Comments	Decreasing water volume in drier conditions reduces herbicide efficacy (note Delta T). Consider increasing water volume in plant stress conditions, but note label limits. Where weeds are susceptible to glyphosate, efficacy is not impaired, however where coverage is important (or weeds difficult to kill) differences were noted.	

Table 1 - Comparing changes in herbicide efficacy with different water volume under hot dry conditions (Milo Farms, Moree)

Nozzle	DG95015E		TT110015-VP	
Nozzle number & pressure	2 @ 2.5 bar		2 @ 2.5 bar	
Spray quality	Medium Fine		Medium	
10% fines (D[v,0.1])	**<131** microns		**<169** microns	
Shield type	Hayes & Baguley			
Tractor speed (km/hr)	7			
Wind 5.7 (km/hr) (adjusted with speed to give net effect)	**Into** (5.7+ 7)=12.7	**With** (7– 5.7)=1.3	**Into** (5.7+ 7)=12.7	**With** (7– 5.7)=1.3
Mean of bolls per plant	**10**	**12.1**	**9.4**	**16.4**
comments	Net wind speed (combined tractor and wind) appears to affect leakage and subsequently yield using glyphosate sprays. This will depend on whether you are going into or with the wind along the row.			

Table 2 - Comparing two examples of leakage while travelling along the row <u>into the wind</u> and <u>with the wind</u> (Moree TAFE)

INTO wind Tractor speed 7 (km/hr) + Wind 5.7 (km/hr) = Net 12.7 (km/hr)

→ ← →

WITH wind Tractor speed 7 (km/hr) - Wind 5.7 (km/hr = Net 1.3 (km/hr)

→ → ←

Nozzle	**DG9502E VS**	**TT11002 VP**
Nozzle number & pressure	2 @ 2 bar	
Spray quality	Coarse	Coarse
10% fines (D[v,0.1])	< **184** microns	< **203** microns
Water volume (L/ha)	110	
Shield type	Hayes & Baguley	
Tractor speed (km/hr)	8.6	
Wind 3.7 (km/hr)	Into (3.7 + 8.6) net of 12.3 (km/hr)	
Delta T (°C)	9.1	
Mean of bolls per plants	**10**	**16**
Comments	With increasing speed, smaller droplet sizes are more likely to leak and affect crop yield (eg. boll retention)	

Table 3 - A comparison of <u>droplet sizes with % fines</u> on boll retention (Moree TAFE)

Nozzle	DG9503E + 2 TP8001EVS	TD CFFC 11003 c/w TQ 15006		DG95015E	TD CFFC 11003 c/w TQ 15006
Nozzle number & pressure	**3** @ 2.5 bar	**1** @ 4 bar		**3** @ 2 bar	**1** @ 4 bar
Spray quality	DG = Coarse TP = Fine	Coarse		Medium Fine	Coarse
Water volume (L/ha)	136	105		96	91
Shield type	**Redball**	**Modified Redball ***		**Polumbo**	
Tractor speed (km/hr)	9.7 (km/hr)			9.8 (km/hr)	
Wind 3.7 (km/hr)	Into the wind, net of 14.8			Cross wind 9.1	Cross wind 19.1
Leakage factor				**1.0**	**0.01**
Delta T (°C)	9.5			10.2	11.7
% leaves with drift spots (Sprayseed)	42.3	15			
Herbicide efficacy				**Peachvine 80%**, Bladder Ketmia 100%, Nagoora Burr 100%	**Peachvine 58%**, Bladder Ketmia 100%, Nagoora Burr 100%
Comments	A shield can be modified to change the nozzle architecture from 3 to 1, reduce droplet size and reduce the effects of leakage			Changing architecture does not impact pattern of coverage, but reducing droplet size can reduce herbicide efficacy	

Table 4 - Comparing modifications to the internal nozzle architecture of a shield reducing nozzles from 3 to 1 (Brookstead & Milo Farms Moree)
** Contact CFI for details of the modifications to the Redball shields on phone (07) 4638 5356.*

Nozzle	TDCFFC 11001 c/w TQ 15003	FL 5VC
Nozzle number & pressure	1 @ 4 bar	1 @ 1.5 bar
Spray quality	Coarse	Very coarse
Water volume (L/ha)	**34**	**91**
Shield type	Polumbo	Polumbo
Tractor speed (km/hr)	9.8	9.8
Wind 3.7 (km/hr)	Cross wind 14.6	Cross wind 19.1
Leakage factor	**0.01**	**0.09**
Delta T (°C)	13.2	11.7
Herbicide efficacy	**Peachvine 48%**, Bladder Ketmia 100%, Nagoora Burr 100%	**Peachvine 70%**, Bladder Ketmia 100%, Nagoora Burr 100%
Comments	Coarser droplets cause less drift but weed control can suffer unless it is compensated by increasing application volume	

Table 5 - Comparing coarse droplets impact on weed control with changing volumes (Milo Farms, Moree)

CFI EFFICACY TRIALS contd. – FIELD RESULTS (CHEMICAL TRIAL)

The aim of shield spraying is to control weeds in the inter-row without damaging the crop, however effective weed control is dependent upon weed species, weather, plant condition etc. The major benefit of translocated (systemic) herbicides like glyphosate is that given the right dosage they allow some compromise on coverage, ie. the mobility of the herbicide within the plant can be compensated by uneven coverage – up to a point. However over time there has been a change in the weed spectrum, where weeds not easily controlled by glyphosate tend to dominate. This has led to the increase use of herbicide tank mixes and as many of the partner herbicides have a contact mode of action, 'good coverage' is required.

The most efficient way for growers using low application volumes to achieve good coverage is to use a FINE spray quality. However, fine droplets increase leakage and subsequent crop damage. The use of coarse droplets can be achieved by changing nozzle type, but this reduces coverage, unless the total volume of water/hectare is increased. The question considered (by CFI) was what risk does adding an alternative herbicide pose to crop safety?

To test this in field conditions a number of herbicides were tested. Crop safety and herbicide efficacy were evaluated. The results from Milo Farms, Moree are outlined below:

	% control Peachvine	Plant details and fruit position from the mean of 30 plants per plot by 4 replicates					
	17 d After Treatment	Veg nodes	Position 1 retention	Position 2 retention	Position 3 retention	Total bolls	Plant height
Chemical Treatments	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
Roundup CT* 1.8L	76.3	8.3	4.0	1.7	0.1	12.0	83.7
Roundup CT 1.8L + Ally 5g	81.9	8.0	3.9	1.9	0.3	12.5	81.4
Roundup CT 1.8L+ Pledge 120g (+ wetter)	99.8	7.8	4.0	1.7	0.4	13.1	84.9
Roundup CT 1.8L + Starane 300ml	87.0	8.2	4.1	1.6	0.3	12.1	81.2
Roundup CT 1.8L + Hammer 75g	91.5	7.8	3.9	2.0	0.3	13.2	86.0
Liberty 3L	91.6	8.2	4.2	2.0	0.3	13.6	81.2
LSD 5%	7.1	NS	NS	NS	NS	NS	NS

Table 6 - Comparing herbicides and herbicide mixtures and their affect on yield parameters using the Polumbo shield (Milo Farms, Moree)

* N.B. Peachvine/Cowvine *(Ipomea lonchophylla)* is not on the glyphosate herbicide label.
All the weeds ranged from 2 – 5 leaf stage
Noogoora burr *(Xanthium pungens)* and Bladder Ketmia *(Hibiscus trionum)* were 100% controlled.
Nozzles were DG9002E X 2 (2 bar) with tractor speed at 9.8 (km/hr) using a Polumbo shield.

This work indicates that there are differences in weed control but none of the herbicide treatments adversely affected boll retention. Further herbicide assessments are required.

3. CONSIDERATIONS WHEN CHOOSING A SHIELDED SPRAYER

There are a number of considerations that growers need to bear in mind when purchasing or using a shielded sprayer. Currently a number of new brands and designs of shields are entering the market and some offer more features than others, eg. variable shield width for different row spacing and a range of locations where nozzles may be mounted. From the trials conducted over the 2002/03 cotton season, it became apparent that all shields leak (spray drift) to some degree. Current investigations have assessed this level of leakage (losses) and evaluated potential crop and yield loss. Research is only just beginning to map the factors that induce leakage (losses).

Growers should be specific on their needs when purchasing a shield sprayer. Some of the following items might be discussed with suppliers,

(1) What are the crops to be inter-row sprayed for weeds?
(2) The row configuration?
(3) The target weeds?
(4) What herbicide(s) are planned to be applied eg; contact or systemic, will there be tank mixes, and what application requirements are required (foliar or lay-by)?
(5) Discuss the filtration and plumbing needs in relation to chemical use
(6) What are the minimum and maximum water (application) rates? and
(7) Are there sensitive crops nearby that need to be taken into account?

The latter two issues affect nozzle selection and location. Sound out your supplier on back up service and query their knowledge on setting up the machine for field operations.

Table 7 outlines some of the points you may consider, based on the issues the project team has come across in working with shields. It is not exhaustive but it outlines some of the problems you may be faced with in field operations.

POINTS TO CONSIDER IN PURCHASING A SHIELDED SPRAYER					
Items to consider	**Sprayer checklist**				
	1	**2**	**3**	**4**	**5**
Are the hoods horizontally adjustable if required for different row spacing?					
What is the number of nozzles per shield and what is the standard nozzle? Consider the nozzle sizes (eg 015 or 03) for the volume range, given speed not exceeding 10 (km/hr) (currently regarded as the middle of the range of operating speeds (8-12 km/hr). The Roundup® Ready label requirements recommend that water volume should not exceed 80L/ha.					
Approach your shield supplier with clear information on average working speed, litres per sprayed hectare, band width to be sprayed and the required droplet size. (This should be done in conjunction with your agronomist/consultant). This is no different to purchasing extra features on a new tractor. Are other options included (eg the option for lay-by sprays)? ONE NOZZLE DOES NOT DO ALL.					
Is there a requirement for additional chemical tanks? Measure the volume marks of each tank purchased using a flowmeter. *Tank volume markings vary.*					
Is the nozzle height adjustable to allow for a variation in target height?					
Does each shield have a parallelogram to allow for better shield tracking? Poor ground-following shields may increase herbicide leakage.					
A cluster of Perspex site gauges are essential in detecting blocked nozzles during spray operation.					
All sprayers tested to date have some drift component. How flexible is it to change nozzles to suit spray conditions? (This may be very important in grain crops).					
Can the nozzles be adjusted up, down or backwards or forwards inside the shield? Checks for obstructions that hinder the nozzle bandwidth inside the shield eg shield walls or skids.					
How do the shields operate, individually or in groups? It maybe useful to be able to turn off a group of shields across the bar eg skip row configuration.					
What sort of controller suits your needs? Have the minimum settings been programmed into the controller? Shields generally operate on low total volume of mixture, so check minimum total litres specification of flow meter. *Remember the chemical rates applied through shields may be expressed as a % of the total area or sprayed area.* How easy is the controller to calibrate? Ask you supplier to assist in re-calibrating your rig with different nozzles, *and check the pressure at the nozzle.*					
Work out the filtration needs for your shields, using a 100 mesh filter, at the chemical tank. This may allow filter removal at the nozzle.					

Table 7 - Points to consider when purchasing a shielded sprayer

4. CPAS LEAKAGE TRIALS – LABORATORY AND FIELD RESULTS

Background

After the 2001/02 season, growers reported yield losses up to 30% when cotton older than 4-leaf was sprayed with RoundUp Ready® glyphosate. Leakage of spray (droplets escaping out from between shields and from the back of shields) and the subsequent deposition on crop foliage, was the probable cause of this yield loss. The shields act as a physical barrier, preventing spray droplets making contact with the foliage.

This paper presents preliminary wind tunnel (laboratory) and field research on the influence of shield height, wind speed (travel speed) and nozzle selection (spray quality) on spray leakage (Plates 1 and 2).

Plate 1 – leakage assessment conducted on the modified Red Ball® shields in the low speed section of the UQG wind tunnel

Plate 2 – The Polumbo shielded sprayer

Laboratory

Trials were conducted in the University of Queensland, Gatton Campus wind tunnel, modified with a new working section that enables boom sprayer sections to be tested in a controlled and contained environment.

Two modified Red Ball® shields were placed side-by-side, in the wind tunnel (contact CFI on phone 07 4638 5356 for details regarding the shield modifications). In between the two shields, string was positioned 5 cm above the ground, to measure leakage onto planting rows directly adjacent to shields. Two meters down wind of the shields, string was positioned across the tunnel 5, 10, 20, 30 and 50 cm above the ground. The shields were held static and the wind speed adjusted to simulate travel speed.

The spray solution contained water plus a fluorescent dye. The operating pressure was 300 kPa. The dye was washed from the strings and samples analysed fluorometrically. Leakage results are standardised against the TP11003-VP nozzle operated at 10km/hr and 2.5 cm above ground level (Figures 1 to 3).

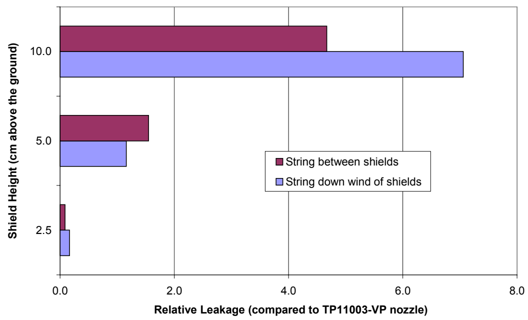


Figure 1 – Leakage results from shield height study

An increase in shield height from 2.5 to 10 cm increased leakage by 50 times.

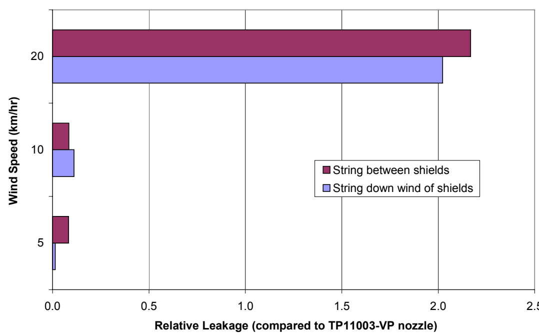


Figure 2 – Leakage results from wind speed study

An increase in the speed range from 5 to 10 km/hr showed minimal change in leakage.

An increase from 10 to 20 km/hr increased leakage by 25 times.

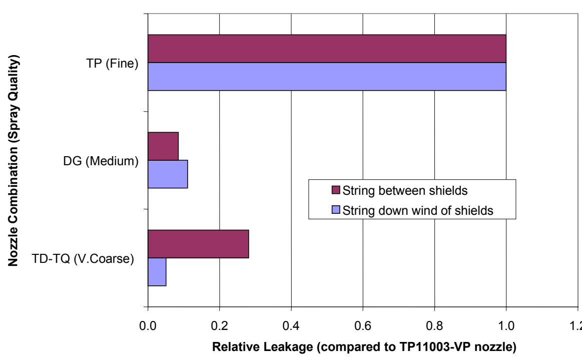


Figure 3 – Leakage results from nozzle selection (spray quality) study

Spray quality changes from FINE to MEDIUM had a minimal affect on leakage.

Spray quality change from MEDIUM to VERY COARSE reduced leakage 10 times.

Field Studies

Seven trials were completed between December 2002 and March 2003, where leakage data from between shields was collected. Three of these trials were carried out in partnership with Conservation Farming Inc. (CFI) where yield and herbicide efficacy was assessed. In this paper, only the Milo Farms trial is presented (Figure 4)

The crop was RoundUp Ready® cotton (50.25 cm high, 40% closure). The spray solution comprised Roundup CT® 490 g/L 1.8 L/ha and fluorescent dye. A Polombo 8 m shielded sprayer was used at 9.8 km/hr travel speed, using six different nozzle combinations (spray quality). The shields sprayed an 80 cm band in the inter-row.

Strings were positioned on the planting line, 5 cm above ground level to measure leakage between shields and were later analysed fluorometrically. Leakage results are standardised against the DG95015E-VS nozzle.

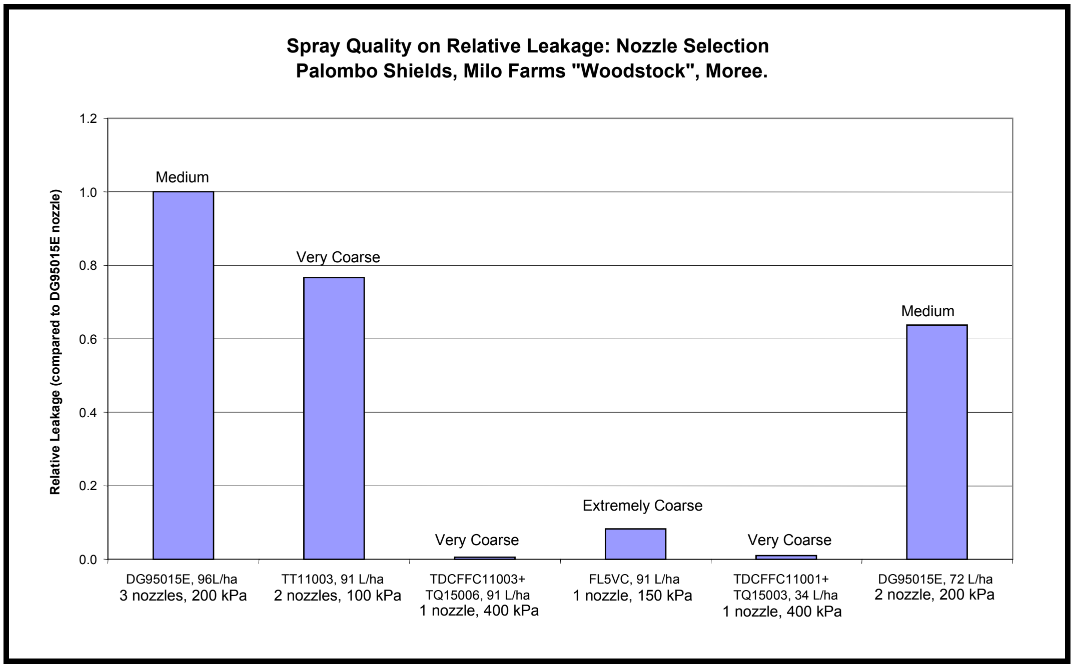


Figure 4 – Leakage results from field studies on Milo Farms, Moree

- Spray drift was reduced by the use of larger droplets (coarser spray quality)
- Using larger droplets may affect coverage and efficacy at lower application volumes
- Minor adjustments to application volume can be made by adjusting travel speed, however increasing travel speed can dramatically increase leakage
- If you want to reduce leakage from your shield use bigger droplets (a VERY COARSE, rather than FINE or MEDIUM spray quality). Note that using larger droplets may affect coverage and efficacy at lower application volumes
- Take care selecting the setup and operating system for the shielded sprayer
- Contact a spray consultant, an agronomist, nozzle manufacturer or sprayer manufacturer and ask for assistance

Conclusions

- Spray quality: Very Coarse (VC) reduces leakage
- Efficacy: maintained by VC spray quality
- Shield height: < 5cm
- Travel speed: 8-12 km/hr
- Spray volume: volume not specified on label - further experimental work needed
- Modifications: do make a difference

Shielded sprayers when setup correctly do 'shape up'

5. *WEATHER* YOU SHOULD BE SPRAYING: WIND, ∆T & STABILITY

Principal
Weather conditions should be within acceptable limits for the safe and effective application of pesticides.

Introduction
The weather plays an important role in controlling the fate of pesticides applied as sprays. The chemical user should check that weather conditions are within acceptable limits before spraying takes place. It is essential that a person engaged in spraying is aware of the effects of wind speed, wind direction, temperature, humidity and most importantly, atmospheric stability, on spray drift. Low cost hand held anemometers and psychrometers are available to monitor these parameters. The purchase of meteorological station data loggers is recommended for larger enterprises regularly involved in the application of agricultural chemicals. Also available are phone accessible weather stations, where current meteorological data is available.

Wind Speed and Direction
Spaying should always be undertaken when the wind direction is away from sensitive areas. If the wind is light and variable in strength or direction then spraying should not take place.

The most commonly cited wind speed limit for general purpose spraying is 15 km/hr, 8 knots or 4 m/s. Above about 15 km/hr, the airborne movement of medium and large droplets downwind from the intended target area may be excessive. In general terms the stronger the wind, the further droplets are able to travel and the smaller the droplets the further they are able to travel, (as their fall speed is much lower). It should be noted however, that turbulence and atmospheric stability also heavily influence the movement of small droplets.

Spraying in winds exceeding about 15 km/hr may require careful consideration of the enhanced risk and the adoption of specific strategies to avoid the off target impact of any spray drift. Under these circumstances a wide buffer zone may need to be established outside the downwind boundary of the sprayed area.

Chemical users should be alert to changes in wind speeds and direction during application and modify or cancel a spray program as necessary.

Strategies
- **Measure wind direction, wind speed, temperature and humidity prior to and during spray application.**
- **Sprays should be applied when the wind direction is away from sensitive areas.**
- **Spraying should not take place if the wind is light and variable in strength or direction.**
- **Chemical users should be alert to changes in wind direction and modify or cancel a spray program as necessary.**
- **Wind speed should be between about 3 and 15 km/hr for most spraying operations.**
- **Spraying should, where possible, be carried out with a cross wind, working into the wind towards the unsprayed area.**

Temperature, Humidity and Delta T (ΔT)
Whenever possible, spraying should be avoided in high air temperatures. Water based sprays evaporate, particularly when air temperatures are high and the relative humidity is low. Evaporation reduces the droplet size of aqueous sprays as the droplets move through the air. Initial droplet size may be increased to compensate for this phenomenon. High temperatures can also mean the onset of unstable atmospheres that may prevent droplets reaching the intended target area.

Delta T (ΔT, or wet bulb depression) is the difference in wet bulb and dry bulb temperatures, as measured for example, using a hand-held whirling psychrometer (Plate 3). High temperatures (>30°C) combined with low relative humidity (<40%, ie a wet bulb depression ΔT >10° C) can increase the rate of evaporation of water based sprays and may subsequently increase spray drift. Delta T can be estimated from a graph (Figure 5) in a three-step process once the (dry bulb) temperature and relative humidity are known. A handheld electronic weather meter, eg Kestral 3000 (Plate 4) can be used for this purpose. Using Figure 5 this is achieved in a three-step process;

(1) Select the recorded temperature (°C) from across the bottom (x-axis) of the graph and draw a line vertically upwards on the figure, then
(2) Select the recorded humidity (%) from the left side (y-axis) of the graph and draw a horizontal line across the figure.
(3) The intersection of these lines is the ΔT value for those conditions.

Alternatively, G.H. Zeal Ltd produce a set of tables that indicate the wet bulb temperature, if the (dry bulb) temperature and relative humidity values are known. The ΔT is then the difference between the wet and dry bulb temperatures. In a different form, a Relative Humidity Table is available at;

www.uswcl.ars.ag.gov/exper/rhtable.htm

Plate 3 - Zeal Whirling psychrometer

Plate 4 -Kestral 3000 hand held electronic weather meter

Strategies

- **Spraying should ideally take place when temperatures are at their lowest (in a 24 hour cycle).**
- **Spraying of water-based sprays should not take place under conditions of high temperature and low humidity ie. when the wet bulb depression (ie. ΔT, a measure of evaporation potential) is greater than about 10°C.**

Atmospheric Stability

Stability is a term used to describe the vertical movement of air in the atmosphere. If atmospheric conditions are unstable, the dispersion of spray upwards may be high, increasing the amount of spray that enters the atmosphere (Figure 6). In contrast, the dispersion rate of droplets may be low in stable atmospheric conditions, leading to high off target deposition of spray at ground level.

If the sky is clear at night, the ground can lose heat rapidly in the dry atmosphere and cool air layers adjacent to the soil surface. Under these conditions air close to the ground becomes cooler than air above. Since this is opposite to the normal condition of the atmosphere, (temperature decreasing with height), the condition is called a surface temperature inversion. Temperature inversions tend to suppress the vertical movement of air and therefore, in effect, present a barrier to the transport of small droplets to the crop canopy. Inversions usually form under very low wind speed conditions. Spraying should be avoided under such circumstances since small droplets are capable of remaining airborne for long periods within the inversion layer and can cause severe damage several kilometres away from where spraying took place.

Spraying should therefore ideally take place in neutral atmospheric conditions (Figure 6). The stability of the atmosphere can be assessed using smoke, or driving a vehicle along a dusty track. Concentration of smoke or dust within a thin layer can indicate the presence of a surface temperature inversion.

Strategies

- **Spraying should ideally take place when atmospheric conditions are neutral.**
- **Do not spray during highly unstable conditions.**
- **Spraying should not take place when surface temperature inversion conditions exist.**
- **Where appropriate, a smoke generating device can be used to determine atmospheric stability.**

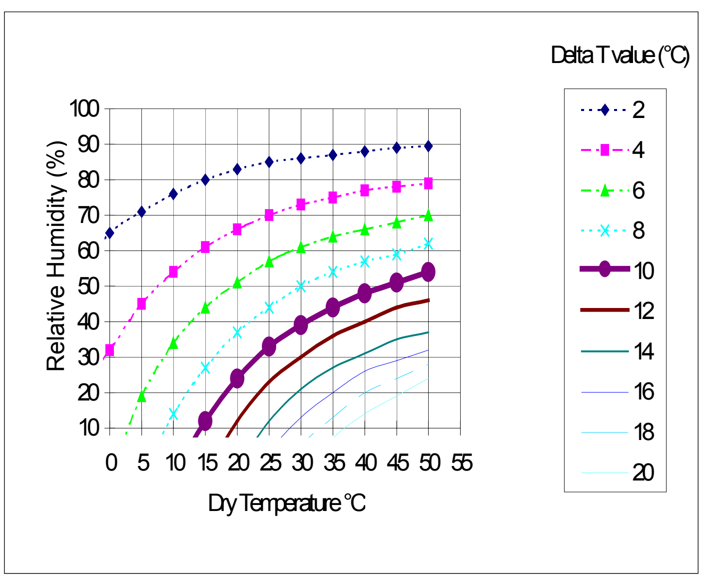


Figure 5 - Relationship between ∆T, temperature and relative humidity

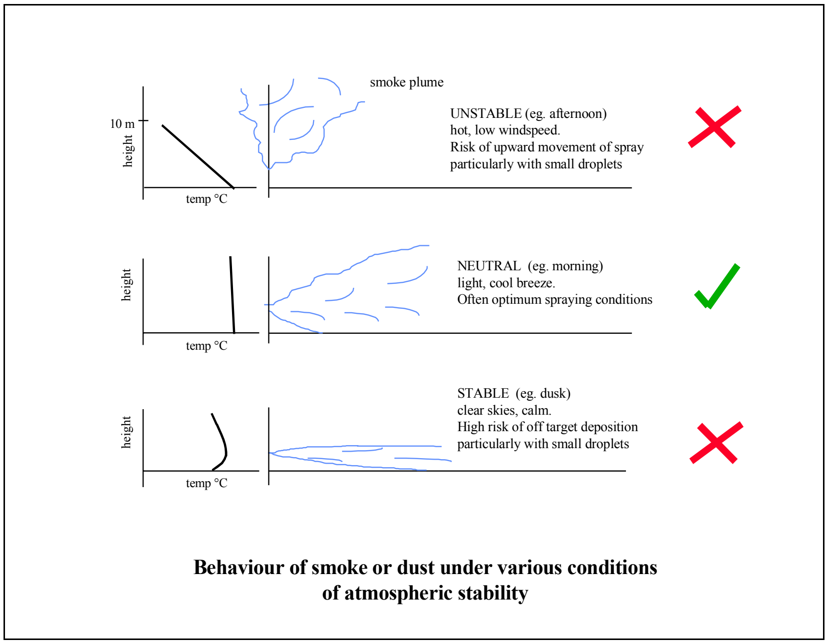


Figure 6 - Basic guide to air stability

References

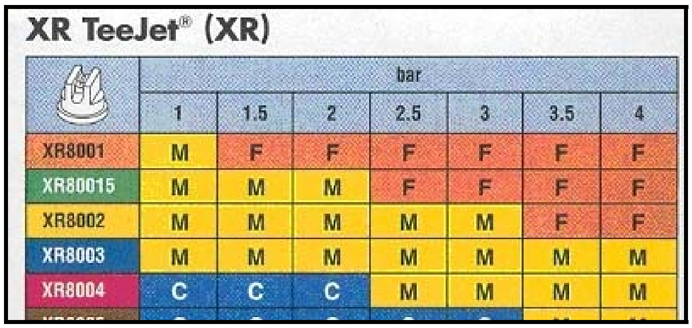
(1) Spray Drift Management, Principals, Strategies, and Supporting Information. (2002). Primary Industries Standing Committee. CSIRO Publishing, Collingwood, Victoria. 71 pp.

(2) Ask G.B. Sprayer Management Handbook. (2002). 2nd Edition. Ed. Graham Betts. Agricultural Spraying Kare Pty. Ltd.

(3) Teejet Agricultural Spray Products Catalogue. (2002). 48M. Spraying Systems Co.

6. UNDERSTANDING SPRAY QUALITY CLASSIFICATIONS (BCPC / ASAE S572)

A number of nozzle manufacturers provide information on the spray quality produced from hydraulic nozzles (for ground application) at various pressures according to the British Crop Protection Council (BCPC) and American Society of Agricultural Engineers standards (ASAE S572). An example of the use of spray quality from the Spraying Systems catalogue is shown in Plate 5. The classifications for spray qualities are **very fine (VF), fine (F), medium (M), coarse (C), very coarse (VC) and extremely coarse (XC).** Spray quality for a nozzle can change depending on the pressure it is operated at. The higher the pressure, the smaller the the droplets, hence the finer the spray quality.


XR TeeJet® (XR)

	bar						
	1	1.5	2	2.5	3	3.5	4
XR8001	M	F	F	F	F	F	F
XR80015	M	M	M	F	F	F	F
XR8002	M	M	M	M	M	F	F
XR8003	M	M	M	M	M	M	M
XR8004	C	C	C	M	M	M	M

Plate 5 - Spray quality classification for part of the range of an XR nozzle (Spraying Systems®)

What Are The BCPC / ASAE S572 Spray Quality Classifications?

The BCPC / ASAE S572 classifications represent spray quality. Spray quality indicates the range of droplet sizes produced by a nozzle and is determined by comparing a nozzle's droplet spectrum at a given pressure against the droplet spectrum of a set of standard reference nozzles. By comparing droplet sizes from a particular nozzle to the reference nozzles the same classification can be obtained regardless of where, when or how it was measured. Droplet size is usually measured by a laser based instrument.

There are three key values in determining the spray quality classification. These values, are taken from the cumulative volume fraction, the D[v,0.1], D[v,0.5] and D[v,0.9] (Table 8). These three values are plotted on a graph to produce boundaries for each spray quality classification. An example of a reference curve from a Malvern laser instrument used for this purpose is shown in Figure 7.

Spray Quality Fraction	Description
D[v,0.1]	10 % of the spray volume exists in droplets smaller than this size (by diameter) in microns, µm.
D[v,0.5] (the VMD)	50 % of the spray volume exists in droplets smaller than this size (by diameter) in microns, µm. 50% of the spray volume is in droplets larger than this size.
D[v,0.9]	90 % of the spray volume exists in droplets smaller than this size (by diameter) in microns, µm.

Table 8 - The three key values that make up the spray quality classification

Reference Curves Are Used To Determine Spray Quality Classifications (Figure 7a).
Each of the different bands on the graph shows the different spray classification. The boundary between two spray classifications is the output of a single reference nozzle. For example Figure 7b shows that the reference nozzle for the boundary between coarse and very coarse has a D[v,0.1] of 210µm, D[v,0.5] of 480µm and D[v,0.9] of 760µm. When commercially produced nozzles are tested against reference nozzles, the output is compared to the reference curves. The white line in Figure 7c shows a nozzle that would be classified as coarse. If any one (or more) of the three critical measures, the D[v,0.1], D[v,0.5] or D[v,0.9] determined for the test nozzle is less than those of a reference nozzle, it is assigned the finest spray quality classification that the D[v,0.1], D[v,0.5]or D[v,0.9] falls within. The nozzle shown as the white line in Figure 7d would then be classified as medium since the D[v,0.1] is in the medium zone.

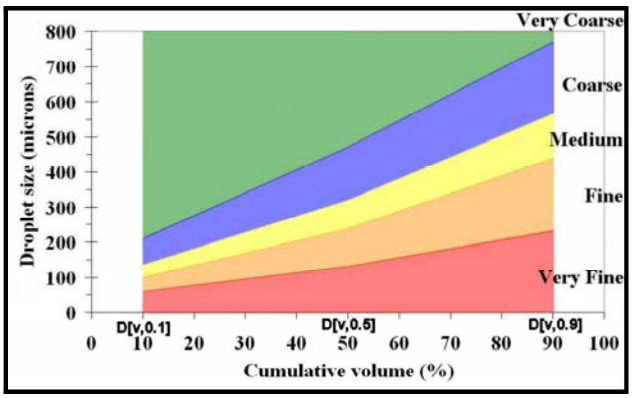


Figure 7a - outputs of a set of reference nozzles

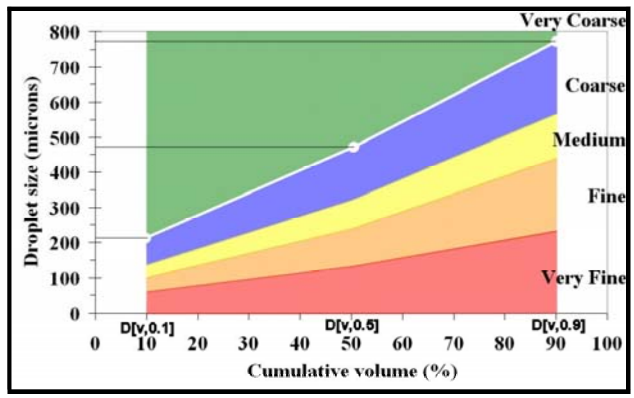


Figure 7b - boundary at coarse and very coarse

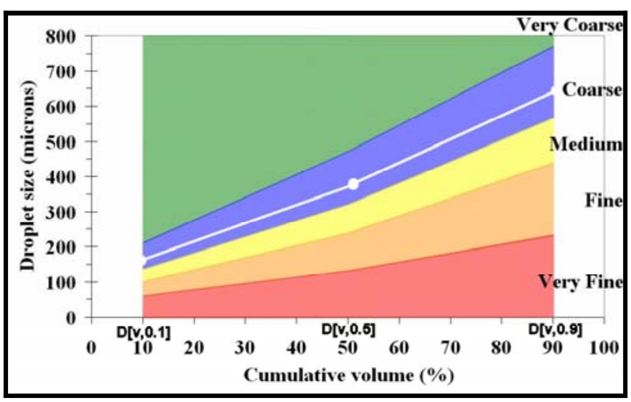


Figure 7c - nozzle that classified as coarse

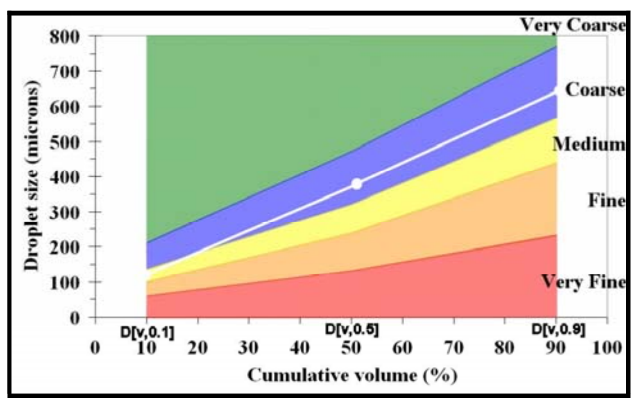


Figure 7d - nozzle classified as medium

Using The BCPC Spray Quality Classifications To Select Nozzles
By using the reference curves in conjunction with the spray quality classifications we are better able to understand the droplet sizes that are produced from a nozzle at any recommended pressure (Figure 8).

For example a XR8001 nozzle at 2.5 bar pressure is assigned a FINE spray quality.

This tells us that this nozzle will have a D[v,0.1] between 60 µm (microns) and 100 µm. and a D[v,0.5] or VMD between 131 and 239 µm.

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

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

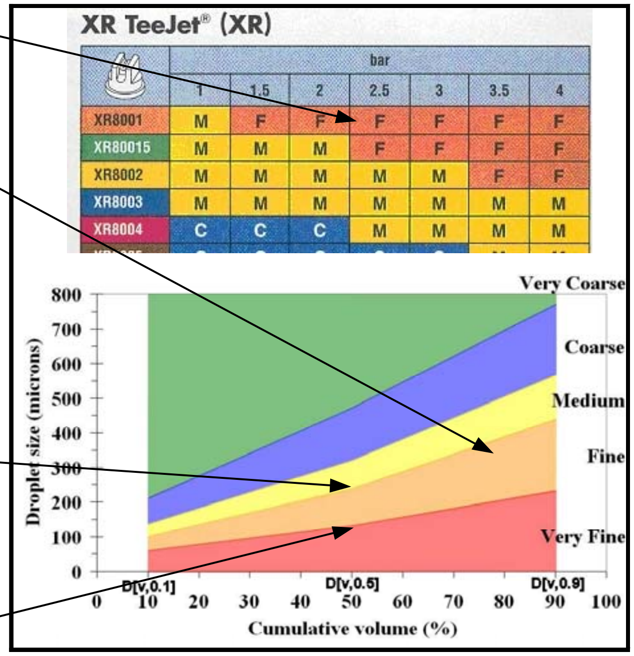


Figure 8 - Understanding nozzle outputs from the reference curve and spray quality classifications

Droplet Behaviour Under Suitable Spraying Conditions

When selecting a nozzle for a particular purpose it is important to understand how droplets of different sizes behave. In general terms droplets in the following size ranges will behave as described below (Table 9).

Approximate Droplet Size (microns, µm)	Expected behaviour under suitable spraying conditions
Less than 50	Will evaporate quickly and will typically be lost before reaching the target
Droplets 50 to 150	Will move with the wind, hence present some risk as they may move off target. But are also very useful under good spraying conditions
Droplets less than 200	Considered 'driftable' because they may reduce in size due to evaporation, and hence move with the wind
Droplets over 350	May bounce or runoff without the addition of adjuvants, hence may not be useful for spraying foliage
Droplets between 100 and 350	Considered the MOST USEABLE fraction when spraying foliage, eg. Useful for many insecticide sprays

Table 9 - Behaviour of droplets under suitable spraying conditions

Using Droplet Behaviour, Reference Curves And The BCPC Classifications To Select A Nozzle For A Particular Purpose

Two things are required when selecting a nozzle for a particular job;

(1) The first is what percentage of the spray volume produced is in the range of droplet sizes we would like for the job (the USEABLE FRACTION). For foliage, the useable fraction is generally between 100 and 350 µm.

(2) The second factor is the risk associated with using that nozzle for a particular job, which can be assessed by determining what percentage of the volume may be considered driftable (the percentage under 200 µm).

Conclusion

The BCPC / ASAE S572 spray classification system for hydraulic nozzle has been adopted in Australia by most of the major nozzle manufacturers and is gradually being accepted and used by regulators and applicators. This scheme can serve as a useful guide for selecting hydraulic nozzles according to their droplet size classification.

References

Further information on spray quality classifications is available from;

(1) SPRAYpak 2

(2) CPAS website, www.aghort.uq.edu.au/cpas

(3) Spray Drift Management, Principals, Strategies, and Supporting Information. (2002). Primary Industries Standing Committee. CSIRO Publishing, Victoria. 71 pp.

(4) Teejet Agricultural Spray Products Catalogue. (2002). 48M. Spraying Systems Co.