



SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 4

Drift management strategies

Minimising and managing spray drift risk

Bill Gordon

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Key points

- Understand the things that the spray operator can change to reduce drift potential
- Spray quality, boom height, spraying speed and tank mix can all impact on drift potential
- Be aware of sensitive areas and label requirements for managing these
- Plan for how you will manage factors that cannot be controlled, such as weather conditions



► GRDC maintains a **Spray Drift** page which conditions additional information on spray drift management. Go to: [Spray Drift](#)

1. Introduction

Almost every pass of the spray rig over a paddock will result in a small amount of the applied product remaining in the air after the spray has been released from the nozzles.



When weather conditions are suitable for spraying, the majority of the product that has become airborne will usually settle back to the ground within a few hundred metres from where it was released, often in the same paddock.

However, if too much of the product is left in the air due to poor nozzle choice, booms being set too high, spraying at high speeds or spraying during the wrong conditions, the consequences can be considerable.

The off-target movement of spray that results in damage to a sensitive area or crop is always the result of poor planning or a bad decision by the spray operator.



Spray drift is taken very seriously in areas where there are sensitive crops, such as grapes or cotton. ►

Photo: Bill Gordon

1.1 Importance of managing spray drift

Apart from the financial incentive to get as much of the product as you can to the target area, there are many other good reasons to minimise spray drift, some of these include:

- **protection of human health – your family, neighbours and community;**
- **protection of trade by avoiding residues on crops and pastures, particularly where residue limits have not been established in the destination market;**
- **protection of farm vegetation, native vegetation, animal habitats and biodiversity;**
- **protection of water quality, including water for human consumption, stock use and irrigation;**
- **protection of aquatic organisms; and**
- **protection of beneficial insects (predators and pollinators) and their refuges.**

To reduce these potential impacts it is important for the spray operator to be able to make changes when required. This necessitates the ability to interpret information, to plan and for the operator to be prepared to change the things they have control over. It is also important that the spray operator is able to make good decisions in order to manage the things they do not have direct control over, such as the weather. This includes the decision to stop spraying when conditions become unsuitable.

2. Understanding the terminology used to describe droplet size and drift potential

2.1 Spray quality classifications

The choice of nozzle and the spray quality (droplet size) that it produces can have a large influence on the level of control obtained. It will also influence the amount of spray that can exist as small droplets, which may remain in the air after each pass of the sprayer.

Spray quality classifications assigned by the American Society for Agricultural and Biological Engineers ASABE, formerly the ASAE) or the British Crop Protection Council or International Organization for Standardization (ISO) are based on measurements of the droplet size produced by a nozzle at a given pressure as compared to the outputs of standard reference nozzles.

ASABE spray nozzle classification by droplet spectra

ASABE standard 572.3 describes the range of droplet sizes produced by a nozzle at a particular pressure. (Colours assigned to spray quality are NOT related to colours assigned to nozzle size.)

UC	XC	VC	C	M	F	XF
Ultra Coarse	Extra Coarse	Very Coarse	Coarse	Medium	Fine	Extra Fine

Very good drift control

Poor drift control

Source: GRDC *Back Pocket Guide*: Nozzle selection for boom, band and shielded spraying



► For more information go to **Module 10: Weather monitoring equipment**

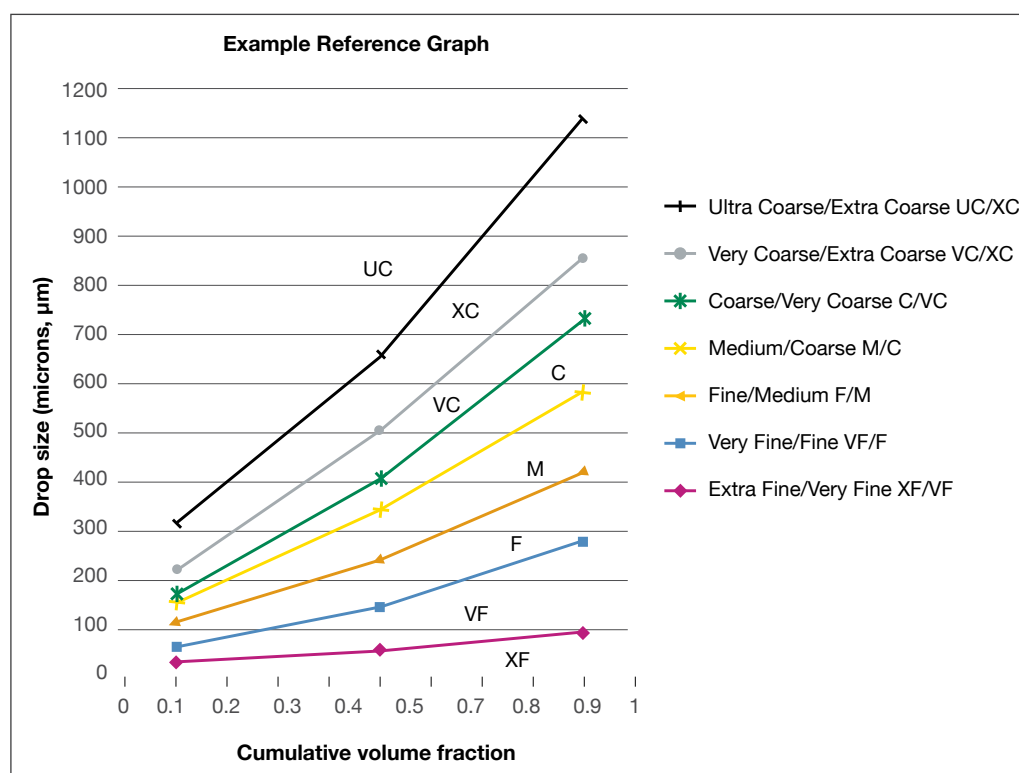
► For more information on nozzle type, design and nozzle selection go to **Module 3: Nozzle design and function** and **Module 5: Spray plans**

While the ASABE, BCPC and ISO systems are not a direct measure of actual drift, they do provide a useful indication of the potential amount of spray drift that a nozzle could produce.

Generally, moving from one particular spray quality classification, to a coarser one should halve the amount of the spray solution that exists as small droplets capable of remaining airborne.

For example, a medium spray quality may have up to 20 per cent of the nozzle output existing as droplets less than 150 micrometres (microns), which are capable of moving with the wind. A coarse spectrum will have less than 10 per cent of the total output as droplets less than 150 microns, and a very coarse will have less than 5 per cent of the total output as droplets less than 150 microns.

Figure 1 Reference nozzle outputs used to determine spray quality classifications



The amount of spray that remains in the air after each pass of the sprayer will also depend on other factors, such as the conditions at the time of spraying, the boom height and the spraying speed.

2.2 Measurements and indicators of drift potential

Spray operators who are focused on reducing the number of drift-prone droplets through the addition of an adjuvant, or by changing nozzles, should seek information detailing the volume of nozzle output at different droplet sizes (microns).

Droplet size and indicative drift potential

- **Less than 100 micron = Highly drift-prone; Difficult to reach the target. Should be minimised where possible.**
- **100-150 micron = May not reach the target. Can move off-target with prevailing wind. May remain suspended under inversion conditions. Susceptible to evaporation, thus further reducing their size and weight.**
- **150 to 200 micron = Should make it to the target, provided boom height is low (50cm from target) and travel speed is less than ~18-20kph. Under hot/dry conditions, droplet evaporation may reduce size to less than 150 micron before reaching the target.**
- **Above 200 micron = Generally expected to make it to the target and less susceptible to evaporation.**



► For more information on nozzles and spray quality go to Module 3: Nozzles design and function

For an adjuvant or nozzle manufacturer to claim drift reduction you would expect to see data that shows a reduction in the number of small droplets, usually less than 150 microns. This requires information comparing droplet sizes before and after addition of the technology.

Caution needs to be used in evaluating this information as you need to be sure that the product is not just reducing the percentage (%) less than a given size by increasing the number of droplets that are generally too large for the intended target. To make such an evaluation it is important to understand some of the scientific terms that are used to describe droplet spectrums.

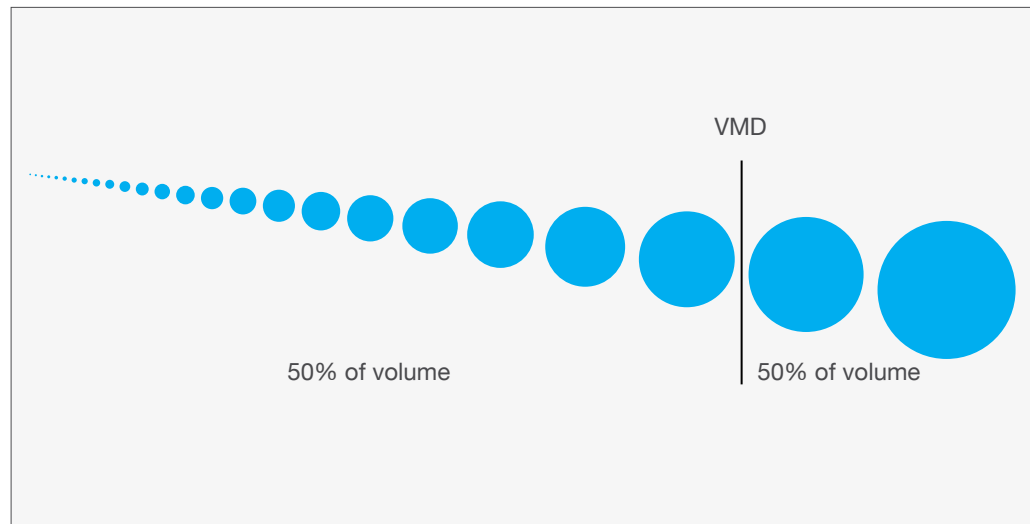
2.3 Scientific terms used to describe droplet size and drift reduction

A number of terms are used on labels, in scientific literature and in manufacturer's technical brochures to describe the range of droplet sizes that can be produced by a nozzle. Some of these include:

μm = is the notation used for micrometers (microns). There are 1000 microns in a millimetre. $Dv_{0.1}$ = the droplet size (diameter in microns) at which 10 per cent of the volume will be smaller than this size. Larger $Dv_{0.1}$ values indicate fewer drift-prone droplets will be produced. $Dv_{0.9}$ = the droplet size (diameter in microns) at which 90 per cent of the volume will be smaller than this size.

VMD = volume median diameter, this is the droplet size (diameter in microns) at which half the volume released from the nozzle will exist as droplets larger than this size, and half the volume will exist as droplets smaller than this size (see Figure 2). VMD is also referred to as $Dv_{0.5}$ in scientific literature.

Figure 2 A visual representation of volume median diameter (VMD).



Span = a term used to describe the range of droplet sizes produced.

The span is a calculated value where **Span** = $(Dv_{0.9} - Dv_{0.1}) \div Dv_{0.5}$

If a nozzle had a calculated span of less than 1, this would mean that the range of droplet sizes produced by the nozzle would be quite narrow.

For example, if a nozzle had a VMD of 300µm, a $Dv_{0.9}$ of 450µm and a $Dv_{0.1}$ of 200µm, then **Span** = $(450 - 200) \div 300 = 250 \div 300 = 0.833$ (a very narrow range of droplet sizes).

If another nozzle also had a VMD of 300µm, but a $Dv_{0.9}$ of 550µm and a $Dv_{0.1}$ of 150µm, then **Span** = $(550 - 150) \div 300 = 400 \div 300 = 1.33$ (more typical of many hydraulic nozzles).

As the span increases in value above 1 this indicates that the range of droplet sizes is also becoming greater.

2.4 How VMD data can be misrepresented to suggest drift reduction

It is relatively easy to increase the VMD of a nozzle at a given pressure by adding substances that increase the number of large droplets in the spray solution. Such increases in VMD can occur without substantially reducing the number of small drift-prone droplets that are produced.

Products that claim to reduce drift potential by increasing the VMD ($Dv_{0.5}$) should only be taken seriously if they also provide data to show a significant reduction in the $Dv_{0.1}$ without adversely increasing the $Dv_{0.9}$ or **span**.

Large increases in VMD without reducing the $Dv_{0.1}$ may actually mean that there will be fewer useful droplets produced for each litre of spray, and, in some instances, many of the droplets produced may be too large to be retained on some targets.

2.5 Terminal velocity of the droplets

Depending on their size, droplets will slow down at different rates as they move away from the nozzle. When they reach the point where they are no longer impacted by the forces that ejected them from the nozzle, but are under the influence of the external environment, they are said to have reached their **terminal velocity**.

Different droplet sizes will have different terminal velocities and will sediment towards the ground at different rates. Larger droplets hold their initial velocity for longer, have greater terminal velocities and will sediment towards the ground faster due to gravity. Smaller droplets lose velocity quickly and remain airborne for longer due to their lower mass.

Table 1 Terminal velocities (metres/second) and time to fall 0.5 or 1 metre for droplets of various diameters in [micrometres (μm)].

Terminal velocities for water-based droplets of various sizes (without allowing for evaporation)			
Droplet diameter (μm)	Terminal velocity (m/sec)	Time to fall 0.5m (seconds)	Time to fall 1.0m (seconds)
50	0.075	6.67	13.33
100	0.3	1.67	3.33
200	1.2	0.42	0.83
500	7.5	0.067	0.13

Adapted from Broadley *et al*, (1990) *Pesticide Application Manual*, 2nd Edition, Department of Primary Industries Queensland, Information series QI89003.

Droplets that are approximately 150 micrometres (microns) or smaller in diameter tend to move wherever the prevailing wind takes them. This can occur both vertically and horizontally. Vertical movement can result from thermal activity or from the 'wake' effect around the sprayer.

2.6 Stop distance of the droplets

The distance a droplet is able to travel through still air after leaving the nozzle (unless intercepted by the target) is known as the 'stop' distance. In the absence of suitable air movement to help the droplets deposit, many smaller droplets will not reach the intended target, particularly when the boom height above the target is too high.

An initial droplet velocity of about 40 kilometres per hour is common for many air-induction nozzles as the droplets leave the nozzle. If you were to operate with a coarse spray quality, you could anticipate that there would be very few droplets produced that are 50µm in diameter; however, one to two per cent of the nozzle output may exist as droplets less than 100µm in diameter, and up to 15 or 20 per cent of the spray may exist as droplets less than 200µm in diameter.

Consider the information in Table 2 (page 9), which shows the distance (in centimetres) that droplets of different sizes can penetrate through still air after leaving the nozzle, relative to their initial velocity.

Table 2 Theoretical distance (centimetres) that water-based droplets of a given size and velocity can penetrate still air.

Initial droplet velocity (km/h)	Droplet diameter in micrometres (µm)		
	50 µm	100 µm	200 µm
1.6	0.3cm	1.4cm	5cm
8	1.7cm	7cm	27cm
40	9cm	34cm	137cm

Adapted from Broadley *et al*, (1990), *Pesticide Application Manual*, 2nd Edition,
Department of Primary Industries Queensland, Information series QI89003.

At a boom height of 50cm above the target and initial droplet velocities common for nozzles currently used, 100µm droplets or smaller would come to a complete stop in the air before reaching the target. Once they have stopped in the air, it is entirely up to the weather conditions what happens to them.

By comparison, droplets that are 200µm in diameter can travel 137cm before reaching their stop distance and are less likely to remain airborne.

When using a medium spray quality as much as 10 per cent of the sprayer output can exist as droplets less than 100µm in diameter. Unless there is a reasonable crop canopy or large standing stubble to catch these droplets, they are more likely to remain airborne and move off-target.

When using a medium spray quality, spray applicators could improve coverage and reduce drift potential by using a narrower nozzle spacing and height control systems that allow for booms to be maintained closer to the intended target.

In summary

When operating the boom at 50cm above the top of the canopy, droplets less than 150 micron will have lost downwards velocity before reaching the target and are therefore subject to movement with wind, inversions or from the wake behind the boom spray.

For a nozzle rated as Medium (M) spray quality, approximately 10-20% of the spray volume will be produced as droplets less than 150 micron, as therefore potentially subject to off target drift. For a Coarse (C) spray quality this will typically reduce to 5-10% of the spray volume.

When boom spray height is raised higher than 50cm above the top of the canopy, droplets up to 200 micron also have potential for off-target spray drift. This increases the volume of spray potentially able to drift to 20-30% for a Medium (M) spray quality and 15-20% for a nozzle rated as Coarse (C).


Under hot and low humidity summer conditions, droplets will be rapidly reducing in size immediately upon leaving the boom. This is especially the case with smaller droplets which have a much larger surface to volume ratio. Droplets that start around 150-200 micron may rapidly reduce in size under these conditions.

Manufacturer nozzle ratings are typically generated with water. Often the addition of pesticides or adjuvants can substantially reduce the average droplet size. Recent wind tunnel trial work suggests that many nozzles may reduce in spray quality by one full spray classification (sometimes more) with many common pesticide mixes. For example, a nozzle rated as Very Coarse (VC) may only deliver Coarse (C) when the pesticide / adjuvant combination is added.

3. Drift management strategies: things that the spray operator has the ability to change

Factors that the spray operator has the ability to change include the sprayer set-up, the operating parameters, the product choice, the decision about when to start spraying and, most importantly, the decision when to stop spraying.

Things that can be changed by the operator to reduce the potential for off-target movement of product are often referred to as drift reduction techniques (DRTs) or drift management strategies (DMSs). Some of these techniques and strategies may be referred to on the product label.

 [Drift Reduction Technology an introduction](#)



► For more information on spraying using larger droplets see the GRDC Fact Sheet [‘Maintaining efficacy with larger droplets - 2,4-D application requirements.’](#)

► For more information on in-crop herbicide application see the GRDC Fact Sheet [‘In-crop herbicide use.’](#)

► For further information see the GRDC Fact Sheet [‘Practical tips to reduce spray drift’](#)

3.1 Using coarser spray qualities

Spray quality is one of the simplest things that the spray operator can change to manage drift potential. However, increasing spray quality to reduce drift potential may require adjustment to water rates used to maintain reasonable efficacy.

Applicators should always select the coarsest spray quality that will provide appropriate levels of control.

The product label is a good place to check what the recommended spray quality is for the products you intend to apply.

In many situations where weeds are of a reasonable size, and the product being applied is well translocated, it may be possible to use coarser spray qualities without seeing a reduction in efficacy.

However, by moving to very large droplet sizes, such as an extremely coarse (XC) spray quality, there are situations where reductions in efficacy could be expected, these include:

- using contact-type products;
- using low application volumes;
- targeting very small weeds and particularly small grass weeds with narrow upright catching surfaces;
- spraying into heavy stubbles or dense crop canopies; and
- spraying at higher speeds.

If spray applicators are considering using spray qualities larger than those recommended on the label, they should seek trial data to support this use. Where data is not available, then operators should initially spray small test strips, compare these with their regular nozzle set-up results and carefully evaluate the efficacy (control) obtained. It may be useful to discuss these plans with an adviser or agronomist and ask him/her to assist in evaluating the efficacy.

3.2 Spraying speed

For the majority of sprayers the most obvious impact of changes in spraying speed is on the pressure at the nozzle. On most sprayers, changing speed alters spray pressure and will result in changes in droplet size. Exceptions to this would be for those operating with manual pressure or pulse-width modulation.

Regardless of the spraying system being used, spraying speed can also influence how droplets behave close to the sprayer.

Increased spraying speeds can have impacts, including

- **at the nozzle, as the droplets are produced, by affecting the spray pattern and increasing small droplet escape;**
- **at the target, by influencing how the droplets may deposit or penetrate a canopy;**
- **altered air movement around the sprayer (aerodynamically), which affects droplet movement close to the chassis (known as the wake effect); and**
- **adjacent to the wheels and tyres, where droplets can be displaced by increased air movement, leading to lower spray deposits.**



Increased spraying speed is one of the factors that can lead to increased spray drift. ►

Photo:
www.sprayers101.com



► **For more information go to Module 6: Pre-operational and regular checks**

3.2.1 Changes in pressure at the nozzle

When using a standard single-line sprayer fitted with an automatic rate controller, increased spraying speed will increase pressure at the nozzles, which will lead to a reduction in droplet size. This is why it is important to prepare a spray plan, so you can determine the range of spraying speeds that will maintain the desired spray quality with the nozzle you have selected, and at the total application volume (litres per hectare) you intend to apply.

There are other spraying systems that can maintain the spray quality over a wider range of spraying speeds, including multi-step systems and pulse-width modulation.



► Go to Modules 16, 17 and 18 for further information on alternative spray systems



► For details on how to assess spray deposits around your sprayer go to Module 21: Assessing spray deposits

3.2.2 Increased escape of small droplets from the spray pattern

Air movement past the nozzle can impact on how the spray pattern is formed and the ability of droplets to remain within the spray pattern. This impact is sometimes referred to as shear, and occurs when air movement begins to impact on the spray pattern.

When the air speed coming into contact with the spray pattern is fast enough, it can:

- change the shape of the spray pattern, causing it to narrow and wrap backwards. This can impact on the overlap of the spray patterns and the evenness of the spray deposits onto the target;
- cause a loss in downward velocity, which can reduce canopy penetration; and
- lead to the escape of small droplets from the pattern, known as detrainment, which can increase drift potential.

3.2.3 Increased wake effect

Increasing spraying speed increases the amount of air displaced by the sprayer as it moves across the ground. This can be significant directly behind the sprayer, where droplets may be transported several metres upwards into the air. Small droplets can be carried upwards by the wake, leading to increased drift potential and areas of lower deposition of droplets in the centre of the sprayer, particularly between the wheels when travelling into a headwind.

The spraying speed at which the wake effect becomes significant can change for different sprayer types. However, in general terms, at speeds above 15 to 16km/h the effect can become apparent.

Spray operators can check the droplet deposition obtained around the sprayer to evaluate the impact of spraying speed and spray quality on where the droplets actually land.



[Assessing deposition in fallow & wheel tracks](#)



► For further information on the impact of air movement around wheels and tyres, see the GRDC Fact Sheet 'Weed control in wheel tracks'

WEED CONTROL IN WHEEL TRACKS FACT SHEET

Improving weed control in wheel tracks during summer fallow spraying

KEY POINTS

- The control of weeds in the spray's wheel tracks and the adjacent area being sprayed is a critical event in the overall success of your spraying operation.
- Weeds in wheel tracks can be controlled by a combination of factors including:
 - the spray pattern
 - the spray speed
 - the spray volume
 - the spray quality
 - the spray timing
 - the spray direction
 - the spray pressure
 - the spray nozzle
 - the spray boom
 - the spray rig
 - the spray operator
 - the spray environment
 - the spray weather
 - the spray terrain
 - the spray crop
 - the spray weed
 - the spray herbicide
 - the spray tank
 - the spray pump
 - the spray hose
 - the spray filter
 - the spray vent
 - the spray cap
 - the spray plug
 - the spray seal
 - the spray gasket
 - the spray O-ring
 - the spray pin
 - the spray bolt
 - the spray nut
 - the spray washer
 - the spray spacer
 - the spray lock
 - the spray pin
 - the spray bolt
 - the spray nut
 - the spray washer
 - the spray spacer
 - the spray lock

3.2.4 Increased displacement around the wheels and tyres

The wheels and tyres on the spray rig tend to displace a lot of air. The faster the rotational speed of the tyres, and the more aggressive the lug pattern is, the more air will be displaced. This tends to move smaller droplets away from the wheel tracks and causes areas of lower spray deposits, particularly at the base of standing stubble. This air movement may also cause droplets to be drawn into the upward air movement behind the sprayer.



► For more information on how to assess spray deposition go to Module 21: Assessing spray deposits

3.2.5 Reduced penetration into stubble and crop canopies

As droplet size increases, the droplets tend to hold their direction of travel. When using coarse droplets, increasing the spraying speed tends to favour deposition on the leading edge of vertical surfaces. Very coarse and larger spray qualities applied at higher spraying speeds can also result in increased shadowing behind stubble, below crop plants and larger weeds. These effects can occur at different spraying speeds for different nozzles, with some nozzles with low-exit velocities being impacted at spraying speeds as low as 8 to 10km/h.

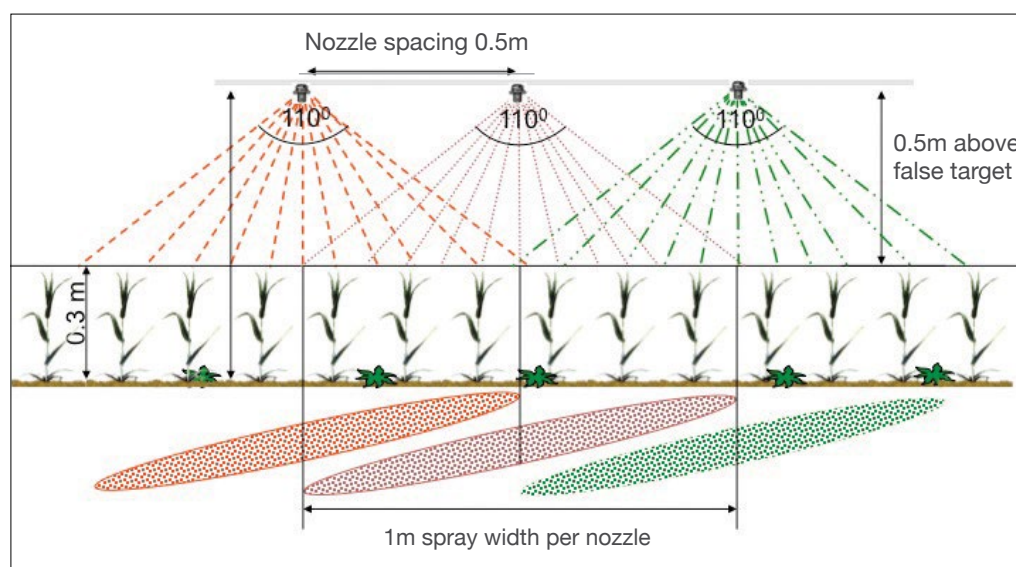
It is worthwhile for spray applicators to assess the impact of spray quality and spraying speed on the deposition of droplets in different situations.

3.3 Boom height

Boom height above the target is critical to ensure an even overlap of the nozzle spray patterns. For most broadacre spraying we aim to set the boom height where we can achieve a double overlap of the spray pattern from each nozzle. Double overlap is achieved when the outer edge of the spray patterns arrive at the target area in alignment with the adjacent nozzle.

The weeds to be sprayed in Figure 3 are 0.02 metres (2cm) high but the false target, the crop, is 0.3 metres high. If we are using 110° nozzles at 0.5-metre nozzle spacing, the nozzles need to be no lower than 0.8 metres above the ground (0.5 metres above false target).

Figure 3 Achieving double overlap



Height above the target affects the overlap of the spray patterns and drift potential. ►

Source: Graham Betts

Wider fan angles can allow for lower boom heights, but the trade-off will be an increase in drift-prone droplets compared to narrower-angled fans (for example, when comparing a 110° nozzle with an 80° nozzle).

While nozzles with narrower fan angles tend to produce less drift-prone droplets than the same type with a wider fan angle, the boom will need to be adjusted to ensure sufficient overlap occurs.

Increasing the boom height above what is required to achieve the overlap will increase the amount of chemical that remains in the air because the smaller drift-prone droplets lose their downward velocity very quickly. The amount of increase in drift potential is related to the size of the droplets, their initial velocity and the rate at which they slow down.



► For more information about height control systems go to **Module 14: Boom stability and height control**

Research has shown that when using the same nozzle type at the same pressure, increasing boom height from 50 to 70cm above the target can increase the amount of drift produced by as much as four times.

An increase in boom height from 50 to 100cm can result in a 10-fold increase in the amount of drift produced for some nozzles.

3.4 Product choice

The choice of active ingredient and formulation can influence the droplet sizes produced by a nozzle, as well as the level of damage that may occur, should spray drift leave the field.

In all situations it should be the responsibility of the applicator to ensure spray drift remains within the treated area.

To provide additional environmental safety, several product labels contain downwind buffer zone requirements, other restraints and directions such as wind speed, spray quality and/or water rates to be used.

Buffer zone information is typically specific to application method. For example the distances may vary from aerial to ground based application. Buffer zones distances may be required for, and differ between, downwind hazards such as bystander areas, natural aquatic areas, pollinator areas, vegetation areas, and/or livestock areas.

Buffer zone information and spray drift label directions are specific to individual products and may vary between different active ingredients and formulation type.

Where downwind buffers or no-spray zones are present on the product label, they can provide a useful basis for identifying which products may present a lower risk than others.

In certain situations it may be recommended to switch to a less damaging active ingredient if there is a known highly sensitive hazard in downwind proximity.

3.5 Rate of product

Robust product rates are important for efficacy and minimising resistance development. However, the rate of product used may also affect the level of damage that could occur if the product moves away from the target area.

The rate of product applied per hectare can influence:

- **the total amount of the active ingredient available to move off-target;**
- **the concentration of the active ingredient within each droplet; and**
- **the concentration of adjuvants and additives within the spray solution, which can impact on droplet size.**

Higher rates of product increase the total amount of active ingredient released into the environment and this can result in the need for increased downwind buffer distances.

Where more active ingredient is released, a greater distance downwind is required to allow for sufficient dilution to occur to reduce the concentration at which the airborne droplets will deposit onto the surface.

Without increasing the total application volume (water rates), higher rates of product mean that each droplet will be more concentrated, this can lead to increased levels of damage if those concentrated droplets deposit onto a sensitive area or crop.

Increasing the concentration of the active ingredients also increases the concentration of other additives in the spray solution. Where products have a high surfactant loading, increasing the rate of product can result in an increase in the number of drift-prone droplets that are produced. In other situations, where the product is formulated as an emulsion, increasing the rate of active may have little effect on droplet size, or may actually reduce the number of drift-prone droplets.

It is important to evaluate the impact that changes in rate or additions to the tank mix may have on droplet size. Assess claims made by manufacturers carefully and access tools that may assist in decision-making.

3.6 Adjuvants and tank-mix partners

The addition of some adjuvants and other products to the tank mix can change the spray quality in ways the spray operator may not have anticipated.

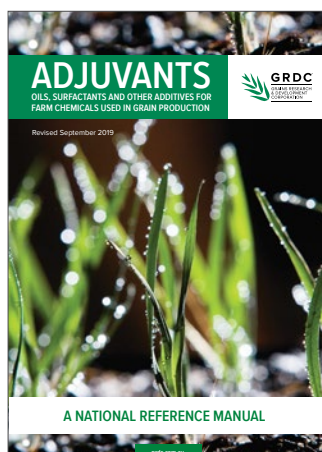
The addition of wetters and spreaders (commonly called surfactants) that reduce surface tension will generally result in smaller droplets being produced, whereas the addition of oils and products that increase viscosity will generally increase droplet size.

Note: Many common ‘spraying oils’ used in Australia are a combination of an oil plus a high rate of spreading surfactant. This can often mean that the benefit of the oil is negated by the surfactant. From some pesticides, the addition of the ‘spraying oil’ may be neutral, or even detrimental, to spray drift.



► **More**

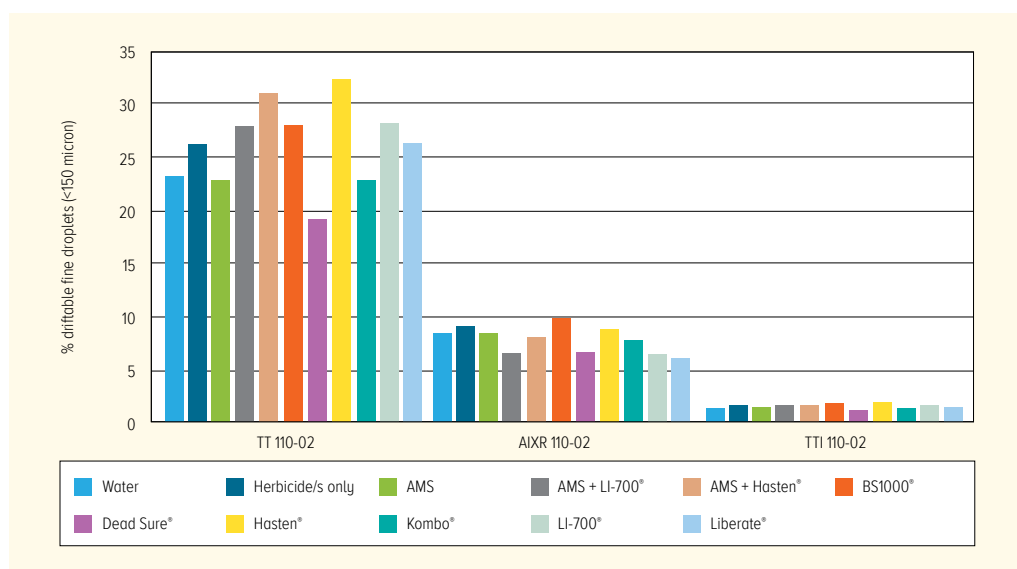
information about the properties of spray adjuvants can be found in the GRDC booklet [‘Adjuvants: Oils, surfactants and other additives for farm chemicals’](#)



To understand how the addition of an adjuvant or other product(s) to the tank mix will impact on droplet size it is important to understand the terminology used to describe nozzle outputs and use this to evaluate the information supplied by product manufacturers very carefully.

Where a manufacturer does not provide detailed information to support claims about changes to droplet size or drift reduction, the spray operator should be sceptical about such claims. All claims should be supported by statements on the Australian Pesticides and Veterinary Medicines Authority (APVMA)-approved label, which tells the spray operator that there is some scientific rigour behind the statements.

Figure 4 Effect of adjuvant type on the volume of ‘driftable fine’ droplets (volume mean diameter (VMD) less than 150 micron) produced by three different nozzles.



A GRDC study (Figure 4) conducted by the Centre for Pesticide Application and Safety (CPAS) at its wind tunnel facility at University of Queensland, Gatton, evaluated the droplet spectrum produced by a range of adjuvant and fallow herbicide combinations across three different nozzle types (all 110-02 (yellow) nozzle size, operating at 4 bar pressure):

- **Turbo TeeJet® (TT) - fine end of medium**
- **Air Induction Extended Range TeeJet® (AIXR) - coarse end of medium**
- **Turbo TeeJet® Induction (TTI) - ultra coarse.**

As can be seen from the graph above, the selection of nozzle type has the greatest impact on the percentage of driftable fine droplets produced.

The addition of ammonium sulphate (AMS and Kombo® type products) typically had minimal effect on droplet size, where it was not mixed with an additional surfactant.

Adjuvants that contain significant levels of surfactant (BS1000®, LI-700®, Liberate®, Hasten®) all increased the volume of spray present as droplets <150 micron with the finest of the nozzles tested (Turbo Teejet®). As the nozzles became coarser, this effect diminished.

The guar gum-based adjuvant Dead Sure® consistently provided a reduction in volume of droplets <150 micron across all the various nozzles and herbicides tested.

A wide range of herbicide combinations were also tested in this study (data for all herbicides and combinations grouped in the graph). Generally, solvent-based herbicides (such as emulsifiable concentrates) or herbicides with in-built surfactant tended to slightly increase the volume of droplets <150 micron, however, the effect of herbicides was typically third in order of importance behind selection of nozzle type and adjuvant, respectively.

3.7 Sprayer type and design features

There are several spraying systems available that have the potential to reduce the amount of spray drift that may be produced, provided they are operated correctly and in appropriate conditions.

In general terms, systems that increase productivity during favourable conditions for spraying can help to reduce the risk of product moving away from the target area, by not requiring applications to be made under unfavourable conditions. Increasing boom width, providing height is maintained, can lead to an increase in the number of hectares sprayed per hour. This can be a positive outcome when weather conditions are good, but can have negative consequences when conditions are wrong, simply by leaving more chemical in the air for each hour of spraying.



▼ **Above left** Shields and shrouds can prevent droplets from becoming airborne.

Photo: Graham Betts

▲ **Above** Target-selectable sprayers can reduce drift by reducing the total amount of product applied to a paddock.

Photo: Graham Betts

◀ **Left** Air-assisted sprayers are widely used in Europe for their ability to improve coverage and reduce spray drift.

Photo: www.desphares.ca/sectors-and-achievements/agricultural-equipment/?lang=en

Spraying systems that have been shown to be able to reduce the potential for spray drift achieve this in different ways, some techniques include the following.

Shielded or shrouded sprayers

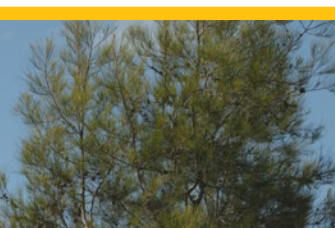
Shielded and shrouded sprayers can reduce spray drift by preventing droplets from becoming airborne. Many designs can reduce spray drift by more than 99 per cent, provided they are operated at appropriate speeds and the shield is maintained close to the ground.

Target-selectable sprayers

Target-selectable sprayers, such as the WeedSeeker® and the WeedIT®, are selective spot sprayers that use 'sensors' to detect and spray only where weeds are found. Generally the weed cover in a paddock will not be more than about 30 per cent, so this can reduce the total amount of active ingredient released over an area, which can reduce the potential for spray drift during favourable conditions. However, often the application rate applied and the concentration in the droplet is significantly higher, so any droplets that do leave the paddock may be of even greater concern.

Air-assisted sprayers

Air-assisted sprayers use conventional hydraulic nozzles and an airstream to assist the transport of droplets to the target. Well-designed and operated air-assisted sprayers can help to constrain droplets within the airstream, reducing the potential for smaller droplets to become airborne.



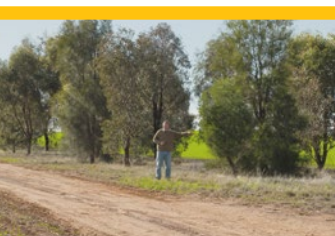
DRT – Vegetative barriers



DRT – Vegetative barriers establishment



DRT – Casuarina



Drift Reduction Technology - barrier structure

In many European countries air-assisted sprayers are legally able to operate closer to sensitive areas than conventional booms. However, if they are not correctly operated, such as using finer droplets and high air speeds when there is little or no crop canopy to catch the droplets, they can increase the amount of drift produced compared to a conventional boom.

3.8 Vegetative barriers

Vegetative barriers are areas of vegetation deliberately planted by the landholder to intercept and filter airborne droplets. Generally, one or two rows of an appropriate species can intercept up to 70 per cent of airborne droplets if they have been chosen to allow for air movement through the foliage and have leaves that are effective at catching small droplets.

The ideal vegetative barrier would be made up of drought-tolerant species with long, thin, cylindrical leaves, such as *Casuarina* species. The vegetative barrier height should be at least 1.5 times greater than the release height of the spray, and it should have a porosity (openness) of about 50 per cent.

Porosity, can be judged by looking at the amount of light passing through the canopy. A porosity of 50 per cent will appear to have about 50 per cent light and 50 per cent dark (foliage) when viewed from a position parallel to the plant line.

The vegetative barrier only needs to be about 15 to 20 metres wide, with an area of about 10 metres free of vegetation on either side, to be highly effective.



Casuarina species are very effective at filtering small droplets from the air. ▲

Photo: Stacey Vogel



► For more information on managing the meteorological conditions go to **Module 10: Weather monitoring for spraying operations**



[DRT - cloud observation](#)



► For more information see the GRDC Fact Sheet '[Hazardous surface temperature inversion](#)'

GRDC booklet '[Weather essentials for pesticide application](#)'

GRDC technical manual '[Meteorological principles influencing pesticide application](#)'

4. Factors that cannot be controlled, but must be managed

The things that the spray operator cannot control, but must be able to manage, include the weather conditions at the time they want to spray, and the sensitive areas and crops that may surround the spraying location.

4.1 Managing weather conditions

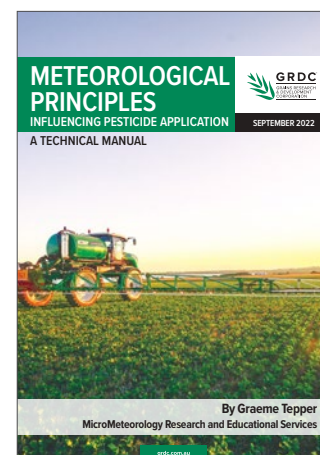
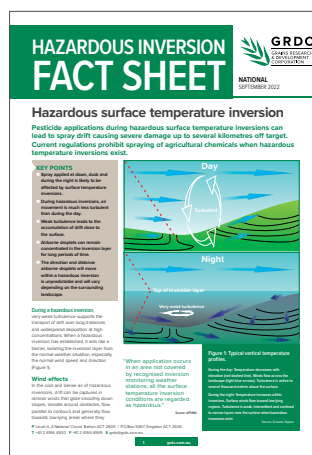
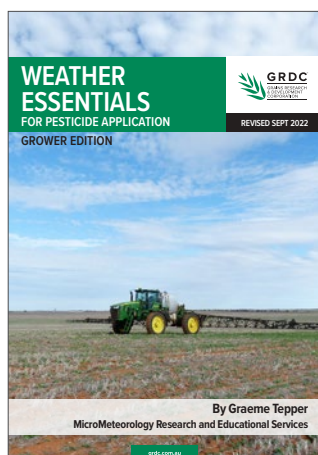
The only way to manage weather conditions during spraying operations is to have access to reliable forecast data, to anticipate when changes are likely to occur, and to closely monitor and measure what the weather is doing at the application site.

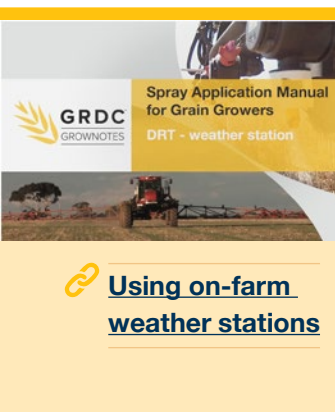
Wind direction and wind speed are the best indicators of the potential risk of off-target movement of product during a spraying operation.



▲ Visual clues, such as smoke and dust, can indicate how the air is moving. Smoke does not disperse in stable air.

Photo: Bill Gordon





Label instructions will often include information about downwind buffers, no-spray zones and suitable wind speeds, which are a useful guide for applicators when planning upcoming spray jobs.

It is critical to read the product label to be aware of the required weather conditions, possible spray-drift restraints and record-keeping requirements.

With recent improved understanding of hazardous inversion conditions and advances in measurement tools, industry has invested in networks of meteorological stations designed to measure and predict the presence of a hazardous inversion. Once a hazardous inversion is in place all spraying needs to cease until the inversion breaks.

COTL (<https://cotl.com.au/>) maintains a network of base stations across the mid-north, mallee and riverland regions of South Australia.

The WAND network (<https://app.wand.com.au/login>), operated by GoannaAg with investment from GRDC and CRDC, covers key broadacre and cotton growing regions from southern NSW to central Queensland.

Depending on hardware installed at individual base stations, typically the site will provide a range of real time meteorological data to assist with spraying decisions. Additionally, sites provide information as to the real time presence or absence of a hazardous inversion, plus a prediction of the presence or absence of a hazardous inversion in 2 hours time.



Example of the meteorological information available from a typical WAND base station. ▶

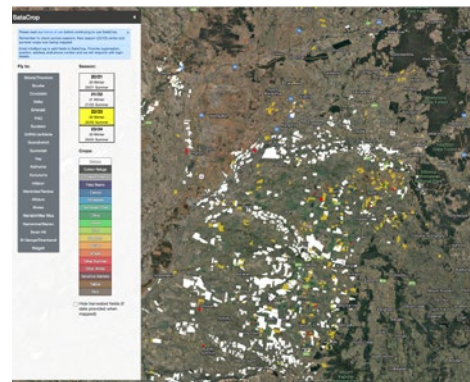
Photo: [The wand network](#)

Goondiwindi		Default <input type="checkbox"/>
As of 18/05/2023 15:30		
All label requirements must be met including wind speed during periods of application.		
Hazardous Inversion	? Absent	
NowCast (until 17:30)	? Present	
Inversion (Vert Temp Diff)	? -0.8 °C	
Wind Speed (2m)	? 10 km/h SW	
Max Wind Gust (2m)	? 14 km/h	
Wind Speed (10m)	? 16 km/h SW	
Delta T	? 7.3 °C	
Temperature	? 22 °C	
Solar Radiation	? 288 W/m2	
Rainfall from 9 am	? 0 mm	
Rainfall 24 hrs to 9 am	? 0 mm	

Note in this example, there is a weak, but non-hazardous inversion currently present, despite conditions where the wind speed is 10-16kph. A hazardous inversion is predicted to develop within the next 2 hours. In this situation, the applicator may consider attempting to complete the current tank load, while watching for further degradation of conditions, but would not to refill. Commencement of spraying should not occur until there is evidence that the predicted inversion has broken.

4.2 Managing sensitive areas

Managing sensitive areas requires a thorough knowledge of what is around the area to be sprayed. Often this requires good communication with neighbours about what they have planted, or are planning to plant. It also requires the operator to do a bit of research. It is a good idea to talk to local advisers, who have knowledge about other crops in the area, and to access websites that may assist in identifying other sensitive areas.



Useful websites include:

- **SataCrop**, www.satacrop.com.au
- **BeeAware website**, <https://beeaware.org.au/> and the BeeConnected app <https://www.croplife.org.au/resources/programs/beeconnected/>
- **Google Earth – for rivers, streams and drainage patterns within your local catchment**, www.google.com/earth

Other useful information may be obtained by:

- **acquiring detailed maps of neighbouring properties;**
- **following label requirements and other technical information from product manufacturers; and**
- **accessing training and participating in stewardship programs.**

Having identified potential sensitive areas, spray applicators need to consult label instructions for possible spray-drift restraints, downwind buffers and no-spray zones, and other directions for use, such as withholding periods.



► **Additional information on planning spray operations can be found in Module 5: Spray Plans**

5. Planning spraying operations

All spray operators need to use wind speed and direction to minimise risk.

Predicted changes in wind direction allow the operator to plan which parts of the property should be sprayed at different times.

Where possible, also plan to treat the paddocks adjacent to boundaries and sensitive areas when the wind direction is away from those parts, particularly in areas where weeds are likely to begin to show signs of stress sooner than other areas (for example, lighter soils for moisture stress).

6. Potential losses when damage from spray drift occurs

The potential for farm chemicals to move off-target and cause damage to sensitive areas is determined by two main factors: the amount of product that is able to be deposited, and the sensitivity of the area or species that the product lands on.

For most spraying activities the amount of product that remains in the air after each pass of the sprayer will be relatively small, depending on the spray quality selected. When using a coarse spray quality the amount of product that remains airborne after each pass of the sprayer may be as low as one or two per cent of the applied rate.

While one or two per cent may seem like a small amount, if we consider the capacity of modern self-propelled sprayers where it is possible to spray more than 60 hectares per hour, the total quantity of product remaining in the air can be large.

If just one per cent of the applied product remains airborne when spraying at a rate of 60 hectares per hour it is possible to leave more than 0.6 of a hectare-worth of product in the air for each hour of spraying that is completed.

If the weather conditions are wrong for spraying and the airborne product moves away from the target site to deposit onto a sensitive area, the damage can be substantial. Where finer spray quality is used, the volume of airborne spray increases significantly.

Consider the sensitivity of some crop species. Many broadleaf crops, such as cotton, tomatoes and grapes may produce visual symptoms of damage to products containing 2,4-D at rates about one gram of the active ingredient per hectare (1g a.i./ha).

At rates above 1g a.i./ha, yield losses may start to occur in some crops, particularly if the product deposits onto a crop when it is in a sensitive growth phase (for example, establishing reproductive structures).

As little as 3g a.i./ha of 2,4-D landing on a cotton crop at the wrong growth stage can reduce the yield of that crop by up to 50 per cent. At a value of \$500 per bale and yield of 15 bales/ha, a 50 per cent loss of yield (equal to 7.5 bales/ha) could easily be worth \$3750/ha in lost income.

Even using a coarse spray quality, just one hour of spraying under surface temperature inversion conditions with 500 millilitres/ha of a 470g a.i. 2,4-D in the tank mix could result in a yield loss to a cotton crop in excess of \$176000.

This calculation is based on spraying 60ha/hour, using 3g a.i. 2,4-D, affecting 47ha, a 50 per cent yield loss, expected yield of 15 bales/ha and price of \$500 per bale. (Note: for the reasons outlined, 2,4-D products must now be applied using a minimum of Very Coarse (VC) spray quality).

While the above example is based on a broad-spectrum product and an extremely sensitive crop, similar estimates can be made for other situations, crops or products..

As little as 20 to 30g a.i./ha of a glyphosate product has been reported to cause damage to cereals at the two-to-three leaf stage.

The pre-emergent herbicide Overwatch(R) (bixlozone) is another example where off-target 'bleaching' on sensitive species can be extremely visual, should spray drift move off the treated paddock. Species such as bifora, sow thistle, lupins, serradella, tillage radish, chicory and biserulla are very sensitive to this herbicide and will typically show the extent of spray drift that has occurred.



➤ **Above left** Overwatch damage to lupins.

Photo: Mark Congreve

▲ **Above** 2,4-D damage to cotton.

Photo: Mark Congreve

◀ **Left** Overwatch damage to sowthistle on roadsides. Photo: Mark Congreve

Spray drift is not just a '2,4-D in summer' issue. The visual bleaching of Overwatch herbicide on sensitive species such as sowthistle is an indicator of the extent of spray drift occurring in autumn applications in some regions. Other products in the tank mix, or other products applied under similar conditions and sprayer setup, are also likely to be moving off-target in similar quantities. Although, due to their symptomatology, the drift from other products may be less obvious to the untrained eye.

Typically it requires the combination of both a very sensitive off-target species and a pesticide with very visual symptoms for spray drift to be easily identified. Many other products may be causing environmental contamination and potentially damage, but without visually observable symptoms.

6.1 Residue limits and the limit of detection

Often we will not see obvious visual symptoms when very small quantities of drifting products deposit onto an adjacent crop. However, if the product that has deposited onto the crop is not registered for use on that crop, or there has not been a residue limit established for this product in the destination market, this can create potential trade issues.

It is important to consider the destination market for an adjacent crop and whether there are animals grazing on neighbouring pasture.. When considering an application next to a crop or pasture, consider how close to harvest the crop may be or when grazing may take place on the pasture. This is particularly important if the crop or produce is being directly exported, for example container shipments of export grains or hay, or situations such as dairy cattle that are milked daily.

All applicators need to be aware that testing for pesticides within Australia that returns a result of 'below the limit of detection' for a product does not mean that produce is free of residue. If more sensitive laboratory equipment is used in a country receiving our exported products, a residue may still be detected.

The only safe time to spray adjacent to an export crop is when the wind direction is consistently away from the crop, and you have managed all the risks you can.

6.2 Spray drift onto houses, gardens, water courses and roof structures collecting rain water

There are many other sensitive areas adjacent to, or within the farm that also require specific protection from spray drift. On many newer product labels buffer zones to these areas will be indicated as required, but it is always good practice to ensure that wind is blowing away from these areas during application.

Causing herbicide damage to the household garden or having insecticide spray drift potentially deposit on the roof that feeds into the rain water tank is generally not a pleasant discussion around the dining table.

6.3 Loss of product efficacy

Under situations where excessive spray drift moves off the paddock, less pesticide will reach the target.

This can result in wasted cost of the pesticide and reduced efficacy, potentially leading to poor control and/or increased selection pressure for resistance from sub-optimal application rates.

7. Summary

Perfect conditions for spraying are rare, and for those conditions to coincide with the most susceptible growth stage of the target weed or pest is even rarer.

To manage this, the spray applicator needs to be able to change their set-up and operating parameters as required.

Things that the spray operator has direct control over, and therefore the ability to change, include:

- **the choice of product and formulation type;**
- **nozzles and operating pressure;**
- **spraying speed;**
- **boom height; and**
- **tank mix partners, including adjuvants.**

Unfortunately spray operators cannot control the weather conditions, they can only monitor and manage what is presented.

Making use of predictive tools and forecast websites can help the operator to make better plans and better decisions.

A reminder about label instructions

Product labels can include instructions about suitable wind speeds and possible downwind buffers or no-spray zones.

This information can be useful for making comparisons about products and equipment set-up, and decisions about how and when to spray.

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 5 Spray Plans Planning for how each product needs to be applied
