CONTENTS

DROPLET SIZE: THE BASICS

CHAPTER SUMMARY

Droplet size has a major impact on droplet behaviour and drift potential. It may affect efficacy:

- Small droplets (VERY FINE to FINE) are the most commonly used size in horticulture

Larger droplets (e.g. COARSE):

- Have more difficulties to deposit
- May compromise coverage, especially at low water volumes
- But have more momentum
- Actively carry further and deeper
- Fall quicker
- Evaporate slower
- Are less affected by wind

Droplet size is measured in 1 micron µm (1/1000 mm). Fine fog measures below 150 µm; rain drops above 600 µm:

- The most commonly used measurement for droplet spectra produced by nozzles is the Volumetric Medium Diameter (VMD).
- The most meaningful descriptions of droplet spectra for nozzles are the British Crop Production Council (BCPC) spray quality specifications, which are in accordance with American Society of Agricultural Engineers (ASAE) Standard S-572

VF	F	M	C	VC	XC
VERY FINE	FINE	MEDIUM	COARSE	VERY COARSE	EXTREMELY COARSE

PROPERTIES OF DROPLETS COMPARISON FINE - COARSE

	FINE	COARSE
Momentum	-	+
Quick fall	-	+
Active carrying capacity, distance	-	+
Swirling Capacity	+	-
Deposition capacity (difficult targets, e.g. onions)	+	-
Deposition capacity (easy targets, e.g. grape foliage)	0	0
Wind resistance	-	+
Droplet survival	-	+
Drift reduction potential	-	+
Coverage (low volumes)	+	-
Coverage (high volumes)	0	0

Figure 1

DROPLET SIZES AND COLOR CODED SPRAY QUALITY CLASSIFICATION.

VERY FINE	VF	●	< 150 µm (fog)
FINE	F	●	177-237 µm
MEDIUM	M	●	238-307 µm
COARSE	C	●	308-459 µm
VERY COARSE	VC	●	459-600 µm
EXTREMELY COARSE	XC	●	> 600 µm (rain)

***Figure 2:** Droplets illustrate only their size relative to each other, not their actual size.*

Liquid crop protection products are delivered from the sprayer to the target area via droplets. These droplets are generally produced by hydraulic nozzles and in horticultural applications generally carried with an air-assist system.

Nozzles produce a range of droplets. Their size may vary from droplets as fine as fog to droplets as large as raindrops (Figures 2 & 3). In many situations the formation of droplets at the nozzle tip will be a critical part of the application process because droplets of varying size behave quite differently. The choice of the right nozzle is therefore critical to achieve efficacy and to balance the risk of drift, especially when an application is carried out under marginal weather conditions.

Small droplets The size of choice for most horticultural applicators. In ideal conditions small droplets should achieve a finer distribution of the pesticide, which can be important for coverage sensitive products, especially with low water volumes. It is much easier for small droplets with limited kinetic energy and velocity to deposit on the target surface. Their swirling behaviour makes it easier to cover the back of targets. On the other hand, small droplets drift away easily and may cause loss or drift damage. Small droplets make the application process largely dependent on good weather conditions. In warm conditions, small droplets may evaporate quickly because they have little velocity, fall slowly and have little volume.

DROPLETS
5

DROPLET SIZE: THE BASICS

COARSE VS FINE

***Figure 3** Coarse spray droplets (left) produced with a TurboDrop® nozzle, compared to fine droplets (right) produced with a conventional XR TeeJet® nozzle.*

DROPLET MEASUREMENT

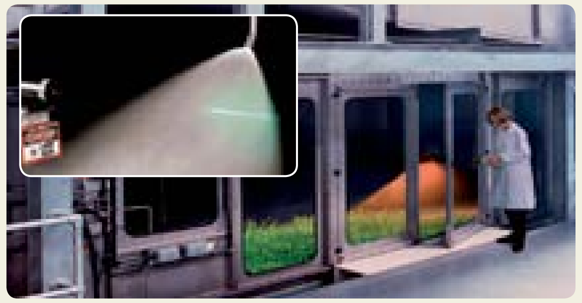


***Figure 4** Wind tunnel in Silsoe, England (Pictured inset: Laser measurement)*

VMD AND DROPLET RANGE

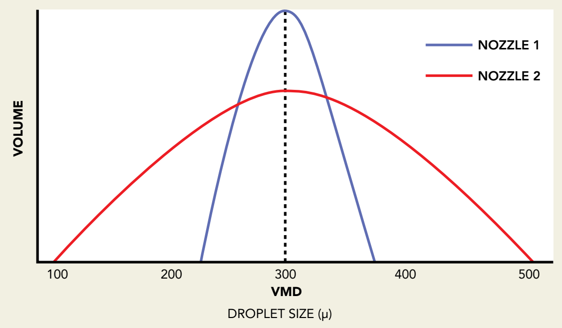


***Figure 5** Source: Croplands/TeeJet®*

VMD MEASUREMENT OF THE SAME NOZZLE WITH DIFFERENT DEVICES IN DIFFERENT LOCATIONS

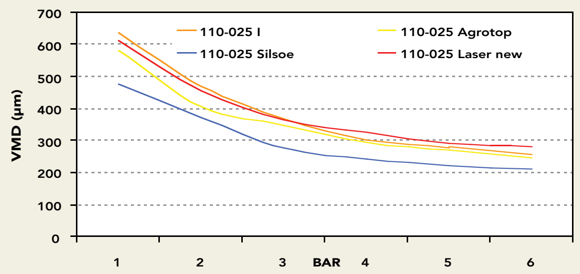


***Figure 7** Source: agrotop*

Large droplets In contrast, larger droplets fall quicker, do not drift as much as small droplets, evaporate slowly, penetrate better into dense or distanced canopies and enable more flexibility during adverse weather conditions. However, they have a lower deposition rate and provide less uniform coverage, especially when low water volumes are used (Figure 1).

DIFFERENCES BETWEEN TWO NOZZLES WITH SIMILAR VMD

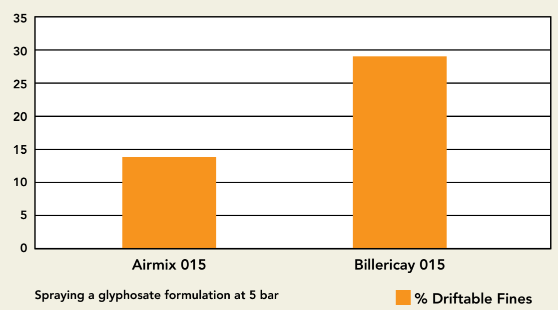


***Figure 6** Source: Centre of the Public Awareness of Science (CPAS), Gatton, Australia 2005*

DROPLET SIZE AND DROPLET SPECTRUM

In order to compare different nozzles it is important to quantify and qualify the size and number of droplets produced. The size of droplets is measured with laser technology in wind tunnels and expressed in microns (1 micron or µm = 1/1000 mm). To compare the droplet spectra of different nozzles four measurements are usually used:

- **Volumetric Medium Diameter (VMD)** is the most commonly used measurement. This is the value where 50% of the spray volume is made up of droplets smaller than this figure and 50% of the volume is made up of droplets bigger than this figure. The VMD describes the average droplet size (based on volume) that a nozzle produces. It is not the description of the range of droplets. Nozzles with the same VMD can have a quite different droplet range (Figures 5 and 6).
- **Dv0.1** - A description for the smaller end of the droplet spectrum. This is the value where 10% of the total droplet volume is smaller or equal to this figure.
- **Dv0.9** - A description for the larger end of the droplet spectrum. This is the value where 10% of

DROPLET SIZE: THE BASICS

TYPICAL NOZZLE SPRAY QUALITY TABLE

agrotop AirMix® Flat Fan	Bar									
	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
AM11001	C	M	M	M	M	F	F	F	F	F
AM110015	XC	XC	VC	C	C	C	C	C	C	M
AM11002	VC	C	C	C	C	M	M	M	M	M
AM110025	XC	VC	C	C	C	C	C	M	M	M
AM11003	XC	VC	VC	C	C	C	C	C	C	M

Figure 9

the total droplet volume is bigger or equal to this figure. Both Dv0.1 and Dv0.9 are used to describe the outer range of droplet sizes that a nozzle produces.

- **Driftable fines** – This figure gives the volume percentage of droplets that are so small they can easily drift away. The cut-off point varies between 141 µm - 150 µm.

REFERENCE NOZZLES AND SPRAY QUALITY

The use of laser technology to measure droplet sizes creates the impression that the industry is achieving high precision by utilising advanced science (Figure 4). Unfortunately this is not quite true. Depending on the laser unit, method used and the location where tests are carried out results for the same nozzle can vary considerably. As a result a VMD value can only be accurately described in relation to the location of the measurement. For example, the same nozzle may produce a VMD of 320 µm in Gatton, Australia, whereas it may only measure a VMD of 270 µm in Silsoe, England (Figure 7).

To overcome these experimental differences the industry has created sets of reference nozzles that produce a standard spray quality. Spray qualities are droplet spectra definitions based on the British Crop Protection Council (BCPC) classification and are in accordance with American Society of Agricultural Engineers (ASAE) standards. Droplet spectra of those standard nozzles can be classified as VERY FINE, FINE, MEDIUM, COARSE, VERY COARSE and EXTREMELY COARSE spray quality. All test facilities must measure the droplet spectra of those reference nozzles with their method to create a reference spectrum (Figure 8). Following this, all other locally measured nozzles can be

DROPLET SPECTRA FOR REFERENCE NOZZLES (SILSOE, ENGLAND)

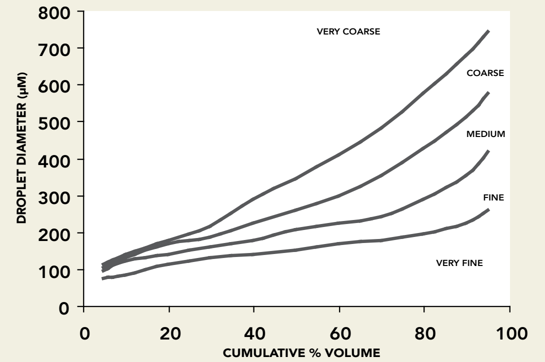


***Figure 8** Source: Paul Miller, Silsoe, England*

classified relative to the locally measured reference nozzles to overcome experimental differences. The result expressed as spray quality (eg. COARSE), rather than as a VMD value, can be compared worldwide. It is therefore more accurate to speak about nozzle performance in terms of spray quality rather than as VMD.

Spray quality depends upon nozzle type, size and pressure used. A typical spray quality table should show all of this information (Figure 9).

While this detailed information is widely available for flat fan nozzles, it is more difficult to get the same kind of detail for cone nozzles used in horticultural spray applications. Traditionally, the overwhelming majority of droplets produced in horticultural tree and vine applications are VERY FINE to FINE spray quality. Horticultural sprayers usually operate in a high pressures spanning from 5 and 20 bar. Under those conditions spray quality does not change widely. Increasing adoption of air induction technology into horticulture creates a larger interest in spray quality. Furthermore to minimise legislative enforced buffer zones, many Australian fungicide and insecticide labels started to specify a minimum spray quality of MEDIUM. No doubt, the future will see more readily available information on spray quality for horticultural cone nozzles.

NOZZLE TYPES

CHAPTER SUMMARY

TREE/VINE SPRAYING

Cone nozzles are the most commonly used nozzle type in horticultural applications. Generally they are operated at high pressures spanning from 5 to 20 bar.

They are available as a fully assembled one-piece nozzle or in self-assembling cone and disc sets:

- Hollow cone patterns generally consist of a VERY FINE to FINE spray quality. Droplets have good deposition behaviour but low velocity (reach)
- Full cone patterns consist of bigger droplets with higher velocity along the center direction of the airstream. Droplets reach further but don't deposit as well. These are good for distanced tree tops.
- Jet streams reach the furthest, but high pressure is needed to break up the stream. These are a good option for distant tree tops.

HERBICIDE/BROADACRE SPRAYING

For herbicide/broadacre spraying the most commonly used nozzles are flat fan nozzles with a 110° spray angle. Different angled flat fan nozzles and off-centre nozzles are often used for under vine and tree spraying.

In general:

- Conventional nozzles produce a FINE to MEDIUM spray quality (1.5-2.5 bar)
- Pre-orifice nozzles produce a MEDIUM spray quality (2-4 bar)
- Low-pressure air induction nozzles produce a MEDIUM to COARSE spray quality (3-5 bar)
- High-pressure air induction nozzles produce a COARSE to VERY COARSE spray quality (4-8 bar)

All flat fan nozzles and some cone nozzles (ALBUZ® TVI and TXB80 TeeJet®) are colour coded according to their flowrate – this colour code is not related to the colour code for spray qualities.

01 015 02 025 03

Spraying with two angled flat fan patterns is advantageous in vegetable spraying and post-em applications with fungicides and insecticides. Nozzles wear, so should be checked regularly and replaced if necessary.

GENERAL

In Australia, more than 1000 different types and sizes of nozzles are available. Every year new nozzles with new claims enter the market. As a result most growers are confused confusing growers. To simplify this important part of the application process, applicators are advised to concentrate on the basics.

In agriculture spray droplets are generally produced with hydraulic nozzles. A pump produces pressure in a spray solution, which forces the liquid through a nozzle orifice. Depending on pressure and nozzle design different spray qualities and patterns can be produced. Two other systems used in horticulture to produce droplets are briefly discussed at the end of this chapter; airshear jets and Controlled Droplet Applicator (CDA) spinning discs.

There are two types of hydraulic nozzles used for chemical application: nozzles that produce a flat fan pattern of various angles and nozzles that produce a cone pattern (Figure 10).

SPRAY PATTERN OF DIFFERENT NOZZLE TYPES

Figure 10

Flat fan nozzles are designed to give equal distribution along a narrow band when overlapping. Hollow cone nozzles, in contrast, give higher application volumes in the overlap areas, resulting in less uniform distribution in a boom (Figure 11). However, hollow cone nozzles can provide more versatility for droplets to penetrate the canopy at different angles. Traditionally they are the favoured type in horticultural applications.

DISTRIBUTION OF SPRAY PATTERNS

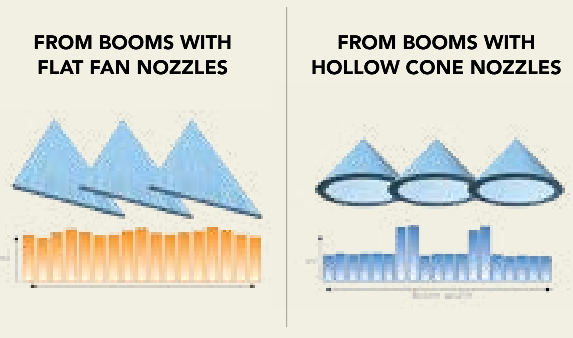


Figure 11

PARTS OF CONE NOZZLES

Figure 12

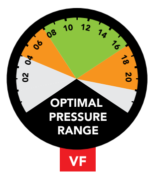
CONE NOZZLES

Cone nozzles can be divided into hollow cone, solid cones nozzles and stream jets. They have three principal parts (Figure 12):

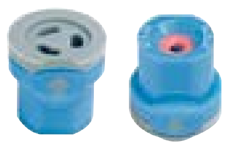
- The Core or swirl plate. The swirl plate has angled slots that force the liquid into a centrifugal spin
- The Swirl Chamber (the space between Core and Disc) allows the liquid to settle into spin
- The Disc (or orifice) meters the final cone pattern when droplets are emerging

Cone nozzles can come as a fully assembled single nozzle body, e.g. ALBUZ® ATR (Figure 13), or in separate parts that need to be assembled into a nozzle body, commonly referred to as Discs & Cores (Figure 12). Pressure used by operators is generally high (5-20 bar) with the optimum being between 8 - 16 bar.

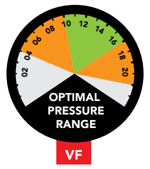
HOLLOW CONE NOZZLES



Hollow cone nozzles produce generally a VERY FINE to FINE spray quality with a narrow droplet spectrum. The disc has no hole in the centre and all the liquid is forced to spin. Droplets emerge with a low kinetic energy and may reach only 2 m (Figure 15). However, generally they are used with air assist that will overwrite this disadvantage. The small, consistent droplet size and the low energy levels favour deposition and coverage making them the preferred nozzle type in air-assist vine and tree spraying.



HOLLOW CONE AIR-INDUCTION NOZZLES



Like in broadacre, drift avoidance becomes an ever increasing problem in horticultural tree and vine applications. Hollow cone air-induction nozzles, such as the ALBUZ ATR, utilise the well proven venturi principle of flat fan nozzles (page 10) to produce coarser droplets. Drift is reduced but so is coverage. The final verdict on use in horticulture is still to come. In New Zealand the Kiwi industry uses air-induction nozzles at certain applications as standard. It works best in combination with well spreading adjuvant technology.

SOLID CONE NOZZLES

In contrast to a hollow cone set-up, the cores of solid cones nozzles have an extra hole in the centre that allows part of the liquid to pass straight to the disc without spinning and to fill the inner cone pattern. Those droplets travel straight with the airstream, have more kinetic energy and may reach as far as 4 m without air-assist (Figure 14). Solid cones are generated with Core & Disc options. The combinations affect angle, volume, droplet size and distribution. The uniformity of droplet size is decreased with the centre hole producing coarser droplets. Distance is improved (Figure 15) but the potential for deposition and coverage on short distance is reduced. Striping may occur if the canopy target is too close. Solid cones are generally used to achieve better coverage on distanced targets such as the top of a tree.

NOZZLE TYPES

COMPARISON OF HOLLOW CONE (RIGHT) WITH SOLID CONE NOZZLE (LEFT)

Figure 14: *With Air-Assist*

Figure 15: *Without Air Assist*

SOLID STREAM JET (or GUN)

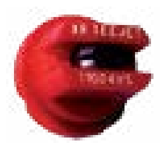
In solid cone nozzles, the bigger the hole in the middle of the Disc the more centred the output becomes. In a solid stream jet design the Core is completely removed, leaving the nozzle with a single orifice in the Disc. All liquid travels in direction of the airstream, has high kinetic energy and may reach as far as 10 m without air assist. Spray quality is even coarser and short-range deposition is further compromised. Because it is very difficult to achieve liquid breakup into droplets with this set-up, it is paramount to use high pressures of around 20 bar or above. Solid stream jets are used to cover even further distanced targets such as tops of tall trees.

HERBICIDE/BROADACRE NOZZLES

For broadacre and herbicide spraying the most commonly used nozzles are flat fan nozzles with a 110° spray angle. They can be grouped into three major categories:

COVENTIONAL NOZZLES

Conventional nozzles such as the TeeJet® XR Extended Range are the simplest nozzle design with only a single orifice. They produce a FINE spray quality (Figure 20, page 12). Larger sizes used in horticultural vegetable applications may produce a MEDIUM or even COARSE spray quality. The XR TeeJet® droplet

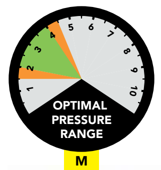


ONE PIECE CONE NOZZLE - ALBUZ ATR

Figure 13

spectrum contains a large amount of driftable fines which makes them high risk for drift incidents. They are best operated between 1.5 - 2.5 bar. Any pressure above 3 bar will generally produce unnecessarily large amounts of driftable fines. The main advantage of conventional nozzles is their low-pressure requirement and their proven performance with fungicides and insecticides.

PRE-ORIFICE FLAT FAN NOZZLES



Pre-orifice nozzles, such as the ALBUZ® ADI reduce pressure internally. They have two orifices: an exit and a pre-orifice. The pre-orifice meters the flow and restricts the amount of liquid entering the nozzle. The restriction causes the spray liquid speed to increase because the corresponding volume must move a greater distance forward in the narrower pipe. According to the law of conservation of energy, the internal

LOW-PRESSURE VERSUS HIGH-PRESSURE AIR-INDUCTION NOZZLES

Figure 16 *Source: agrotop and TeeJet®*

AIR-INDUCTION NOZZLE MODE OF OPERATION

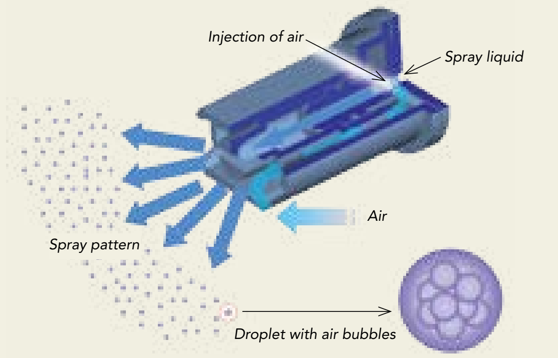


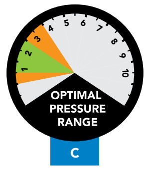
Figure 17 *Source: agrotop*

pressure within the fluid has to decrease. As the liquid leaves the exit chamber, fewer and bigger droplets are formed at the larger exit orifice.

Compared with conventional nozzles, drift may be reduced by 50% (Figures 19 and 21). Pre-orifice nozzles should be operated between 2 - 4 bar. Generally pre-orifice nozzles produce a MEDIUM spray quality, desirable for fungicide and insecticide applications. At low-pressure they produce a COARSE spray quality. However, those coarse droplets consist almost entirely of fluid, have few air inclusions and behave at the moment of impact differently to air inclusion droplets of the same size. These solid coarse droplets have greater momentum and are more prone to bounce off the target. Coarse droplets are better produced with air induction nozzles. Turbo TeeJet® nozzles are difficult to clean and should only be used if good boom line hygiene can be maintained. It is advisable to always carry some spare nozzles in the field.

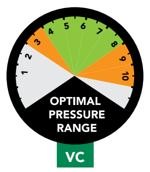
AIR INDUCTION NOZZLES Air induction nozzles also feature two orifices. The pre-orifice meters flow and determines the size of the nozzle. The exit orifice is generally twice the size of the pre-orifice. Similar to pre-orifice nozzles; the pre-orifice of air induction nozzles restricts flow and in conjunction with the mixing chamber creates an internal pressure drop in the spray fluid. However, the difference of the air induction nozzle is that it contains an venturi (air aspirator) between the two orifices. This small tube corresponds with the outside. The atmospheric pressure of the outside air is higher than the reduced internal pressure of the spray solution. As a result the venturi draws air bubbles into the liquid stream (Figure 17). The spray spectrum created at the bigger exit orifice consists of coarser droplets filled with air (Figure 17). Air induction nozzles produce fewer driftable fines and are excellent tools for drift reduction. There are two types of air induction nozzles: low-pressure air induction nozzles such as the agrotop AirMix® and high-pressure air induction nozzles such as the ALBUZ® AVI or agrotop TurboDrop® (Figure 16).

Low-pressure Air induction nozzles operate best between 3 - 5 bar. They generally produce a COARSE spray quality, but with higher pressure a MEDIUM spray quality can also be achieved. Low-pressure air induction nozzles are half the price of high-pressure air induction nozzles and depending on size, can be excellent all-rounders. Compared to conventional nozzles they produce 80–90% less driftable fines (Figures 19 and 22). Low-pressure air induction nozzles are the most popular nozzle type sold in Australia.



Most manufacturers fit their boom sprayers with low-pressure air induction nozzles as standard.

High-pressure Air induction nozzles produce a COARSE to VERY COARSE spray quality. They are best operated between 5 - 8 bar and produce even less driftable fines than low-pressure air induction nozzles. Compared to conventional nozzles, reduction of driftable fines is around 95% (Figures 19, 23 & 24). At speeds of around 25 km/h and above, high-pressure air induction nozzles provide more flexibility in retaining a constant spray quality at the same water rate/ha with varying speeds.



NOZZLE TYPES

DROPLET SIZE FOR A RANGE OF 02 FLAT FAN NOZZLES

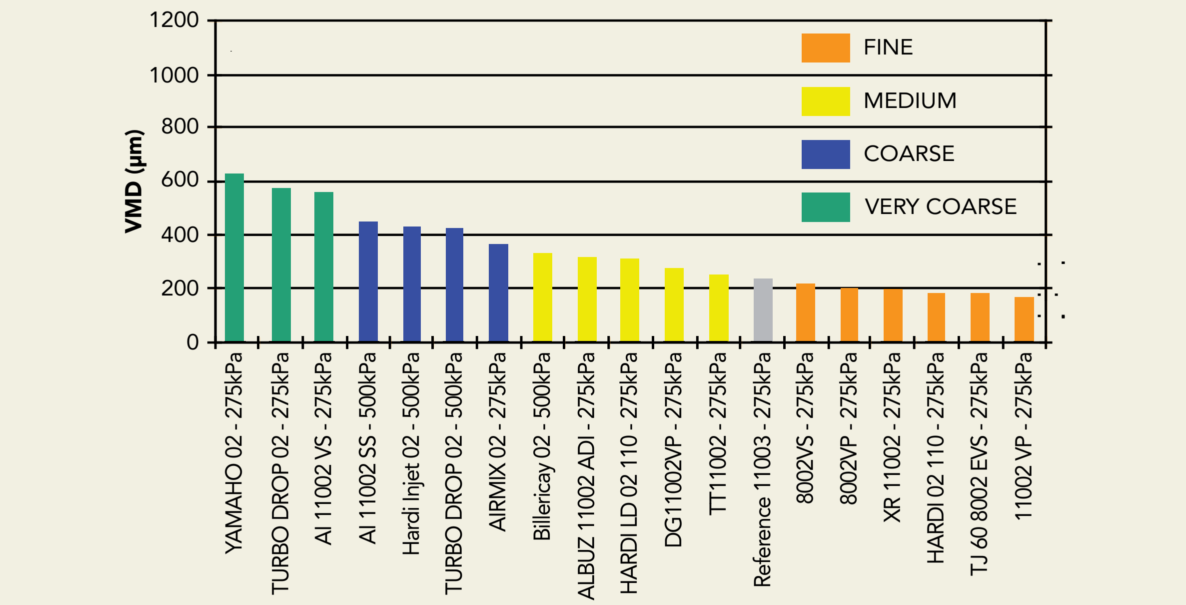


Figure 18 *Source: Chris O'Donnell, Centre for Pesticide Application & Safety, The University of Queensland*

AIRBORNE DRIFT 2M DOWNWIND FROM NOZZLE

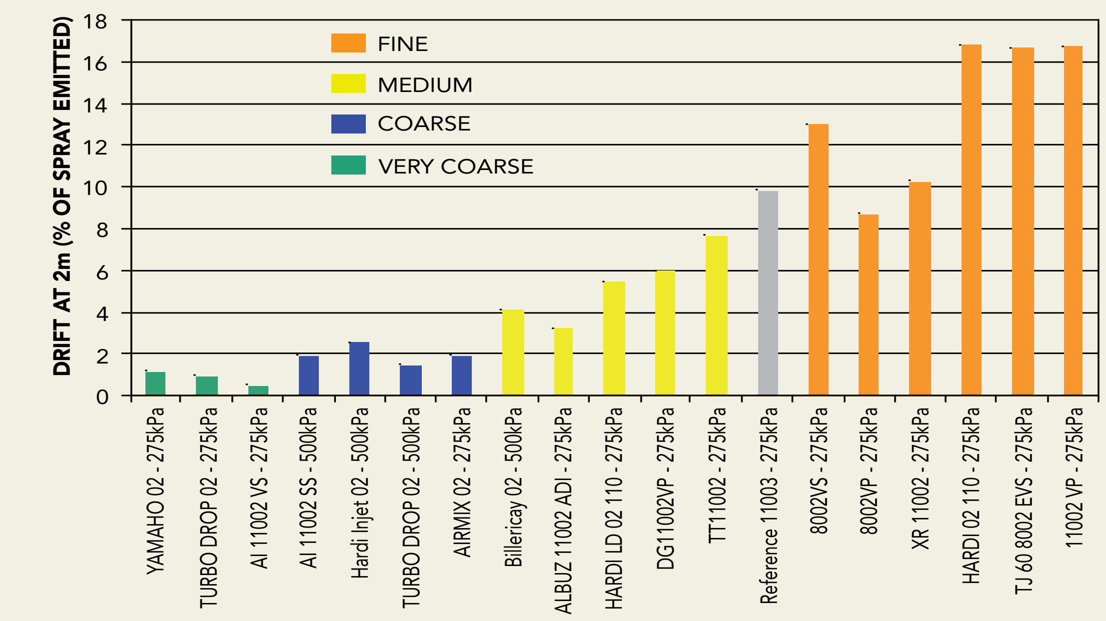
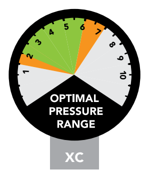


Figure 19 *Source: Chris O'Donnell, Centre for Pesticide Application & Safety, The University of Queensland*

Extremely Coarse One nozzle design produces this spray quality consistently. The TTI nozzle is in principal a Turbo TeeJet design with an air induction venturi. Over a wide pressure range (2 - 7 bar) it produces EXTREMELY COARSE droplets. The amount of drift is reduced by around 99% (Figure 19 and 25). However, coverage, especially on small targets is questionable. Current advice is to use these nozzles only with high water volumes (e.g. under tree and vine spraying) or otherwise, if the need for drift reduction is paramount over efficacy (e.g. 2,4-D spraying at night in cotton areas). In those situations they are ideal for translocated products (e.g. glyphosate, 2,4-D) on large targets.



NOZZLE TYPES

XR TEEJET® 110-02 NOZZLE

2.5 bar "FINE"

Figure 20

TURBO TEEJET® 110-02 NOZZLE

3 bar "MEDIUM"

Figure 21

AGROTOP AIRMIX® 110-02 NOZZLE

3.5 bar "COARSE"

Figure 22

AI TEEJET® 110-02 NOZZLE

5 bar "COARSE"

Figure 23

AGROTOP TURBODROP® 110-02 NOZZLE

5 bar "EXTREMELY COARSE"

Figure 24

TT TEEJET® 110-02 NOZZLE

3 bar "EXTREMELY COARSE"

Figure 25

The amount of drift is reduced by around 99% (Figures 19 & 25). However, coverage - especially on small targets - is questionable. Current advice is to use these nozzles only with high water volumes (e.g. under tree and vine spraying) or otherwise, if the need for drift reduction is paramount over efficacy (e.g. 2,4-D spraying at night in cotton areas). In those situations they are ideal for translocated products (e.g. glyphosate, 2,4-D) on large targets.

NOZZLE TYPES

DROPLET TRAJECTORY OF FLAT FAN NOZZLE COMPARED TO ANGLED TWIN NOZZLE

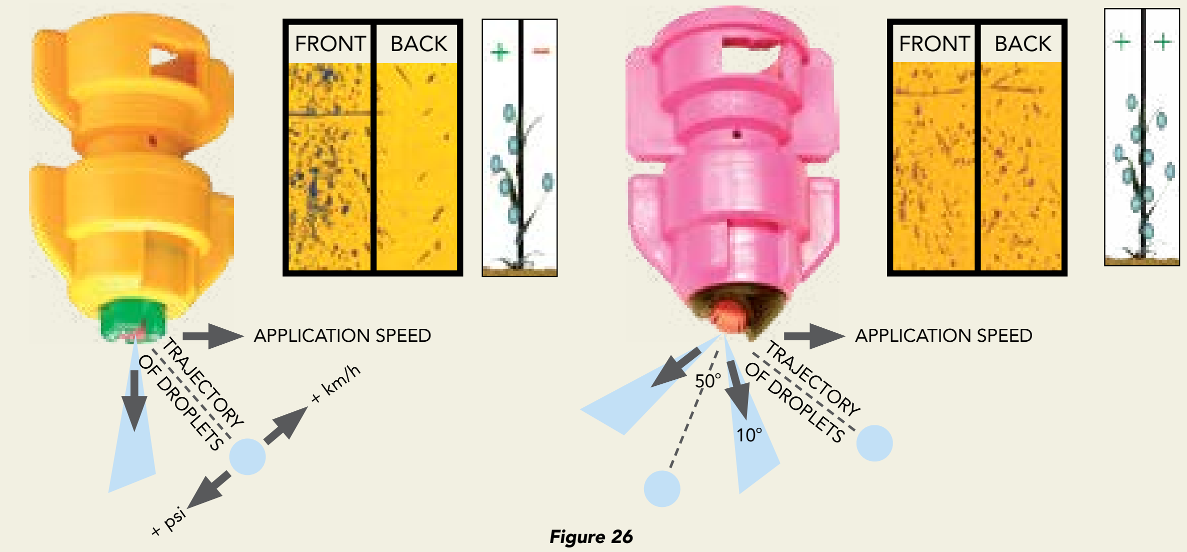


Figure 26

TWIN CAPS

Figure 27

TWIN CAP SPRAY EXAMPLE

Figure 28

SPRAYING IN ANGLES

This nozzle set-up is an excellent choice for vegetable applications (Figure 28), especially in vertical crops such as onions.

Application speed has an important influence on droplet trajectory. The coarser the spray quality, the more important this factor becomes, larger droplets have more initial momentum and greater velocity.

Traditional flat fan nozzles face vertically downward. During application the force from the driving speed deflects the downward orientated droplets forward (Figure 26). Consequently when the target area is reached, the droplet trajectory is forward orientated. The higher the speed the more pronounced the effect. The coverage of the backside of target plants is always compromised under these circumstances. In knockdown, pasture or fallow situations this is generally not an issue. Particular post-em applications with fungicides and insecticides can suffer from insufficient plant coverage.

Hollow cone nozzles have a fit in these situations at very low speeds. However, there are a number of flat fan nozzles with an angled spray pattern available to overcome this problem more efficiently, e.g. ALBUZ® CVI Twin, Twinjet, TeeJet® Turbo Twinjet, DG Twinjet or agrotop HS. The most versatile angle set-up for speeds up to 10 km/h consists of a twin cap nozzle body that can be fitted with conventional XR TeeJet® or agrotop AirMix® nozzles or any combination of them (Figure 27). However, the backward orientated fan is - like most other angled nozzles - only 30° and too low to overcome the forward orientation at higher speed. A nozzle such as the agrotop HS with a 50° backward orientation enables a backward droplet trajectory with speeds up to 15 km/h. For both, the 30° and the 50° options, the desired outcome becomes unreliable with faster driving speed and depends increasingly on calm wind conditions.

NOZZLE NOMENCLATURE

Nozzle name:

agrotop TDAM-110-03

agrotop = Manufacturer

TDAM = AirMix®

110 = 110° spray angle

03 = size (0.3 gallons /min at 2.8 bar)

Figure 29

COLOUR CODING OF FLAT FAN NOZZLES

Figure 30

EFFECT OF NOZZLE MATERIAL ON NOZZLE WEAR: ACCELERATED WEAR TEST

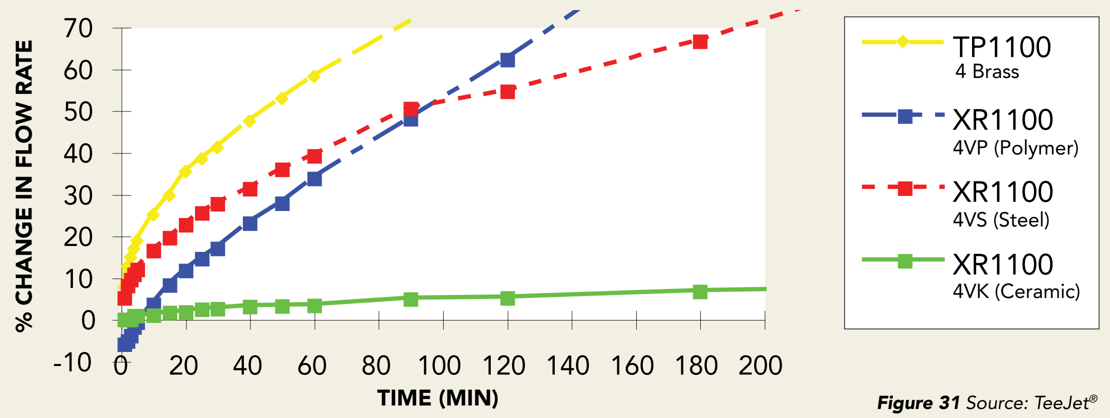


Figure 31 *Source: TeeJet®*

NOMENCLATURE

Flat fan nozzles Nomenclature for flat fan nozzles is simple. Names of nozzles generally start with the name of the manufacturer, e.g. Agrotop The first letters in a nozzle name refer to a specific type of nozzle (Figure 29). For example TDAM represents (TurboDrop) AirMix.®

The specific nozzle type code is followed by the spray angle that a nozzle produces. In most cases this would be 110 for a 110° angle but there are for example 65, 80 or OC (off-centre) codes.

The next code number represents the standard size of the nozzle. The size is determined by the spray volume that a nozzle puts out at 2.8 bar. For example, a XR TeeJet® nozzle 02 size means the nozzle puts out 0.2 gallons/min (flow rate of 0.75 L/min). A 04 sized nozzle has a flow rate of 0.4 gallons/min and so on. Different type nozzles of the same size may produce completely different spray qualities but they will have the same flow rate per minute.

Any letters behind the size-code indicate this nozzle is manufactured with different orifice materials. For example, VK stands for ceramic, VS for steel and VP for polymer. No letters generally indicate there are no options.

Hollow cone nozzles There is no standard nomenclature for those nozzles. Some types are just named by the colour, e.g. ALBUZ® ATR yellow. Other ones are named in order of manufacturer sizes e.g. TX-VK 26 TeeJet®. Some are following the ISO standard such as the ALBUZ® TVI and the TXB80 TeeJet® ranges. In any case, to compare cone nozzles of different types the user needs an appropriate table (Figure 83, page 49).

COLOUR CODING

Flat fan nozzles Flat fan nozzles of the same size are ISO colour coded to simplify recognition. For example, regardless of type, every yellow flat fan nozzle is a size 02 (Figure 30). For assembled air induction nozzles such as the Agrotop TurboDrop® the size is determined by the pre-orifice containing injector part, not the output-orifice containing nozzle cap.

This colour coding also applies to angled, twin and off-centre flat fan nozzles. However, it does not apply to cone nozzles.

Hollow cone nozzles The colour coding for cone nozzles is somewhat confusing. Few, such as the ALBUZ® TVI or TXB TeeJet® range have introduced ISO colour coding and sizes according to flat fan standards. For example, a red ALBUZ® TVI 04 at 5 bar will have the same output as a red agrotop AirMix® at 5 bar or a red TeeJet TXB-04. All of those are colour coded. However, they are very different in output to a red TX-VK06 TeeJet®, or a red ALBUZ® ATR that are not colour coded. Figure 83, page 49 compares colours of four cone nozzle types. Each column contains equivalent sizes for each of the four types and their output at different pressures.

Discs and Cores Discs and Cores can't have colour coding but have synchronised sizes. For example, an ALBUZ® AD 3 AC 45 (Figures 84, page 49) combination has the same output as a D3 DC45 TeeJet® combination.

NOZZLE MATERIAL AND WEAR

Nozzle orifices are produced with different materials, the most durable of them being ceramic, followed by steel and various polymers (Figure 31). Brass orifices are made from the least durable material and are rarely sold any more.

Cone nozzles for horticultural use should be made out of ceramic to withstand high-pressure and abrasive materials.

Worn or damaged nozzles will produce an uneven spray pattern with serious implications for efficacy, especially in boom situations. Worn or damaged nozzles in spray units without an automatic rate controller will increase the output, spoil calibration, and may create unnecessary extra costs due to over application.

Most new sprayers have rate controllers that will compensate by measuring liquid flow and adjust accordingly. However, they will cause undersupply to the rest of the nozzles to adjust for the extra output of the worn nozzles. Again, this may result in an uneven spray pattern.

Nozzles should be checked for wear at least once per season. As a rule of thumb, nozzles made from durable plastic will need replacement every two years, nozzles with steel orifices should be replaced every three years and nozzles with ceramic tips should be replaced every four to five years. These timeframes will decrease with heavy use, especially when spraying abrasive chemicals.

DROPLET PRODUCTION WITHOUT NOZZLES

Droplets in horticultural situations can also be produced without nozzles by using airshear or Controlled Droplet Applicator (CDA) technology. Both technologies provide a VERY FINE spray quality and use low water volumes.

AIR SHEAR JETS In Air shear Jets droplets are produced by dripping them into a ducted very high velocity airflow up to 350 km/h. This technology produces VERY FINE spray quality and is usually used with low water volumes. Droplets have a very high kinetic energy and travel directly with the airflow. While the droplet formation is not of concern the air assist delivery system into the canopy is (see page 20).

CDA The spray liquid is fed onto a spinning disc. Centrifugal forces break the liquid into small droplets. The droplets rotate with low kinetic energy in an almost 90° angle of the disc. Droplet size can be changed by adjusting the speed of the Disc but the output is generally a VERY FINE spray quality.

IMAGE TITLE

ROOM FOR AN IMAGE HERE?

CHAPTER SUMMARY

- Air assisted machinery opens up the canopy and carries droplet further
- Generally, the larger the canopy the more air is needed
- Turbulent air is better in opening up canopies
- Airblast technology is best suited for dilute applications in medium to sparse canopies
- Straight through axial fan technology is versatile and equally suited for large and small, dense and sparse canopies, dilute and Concentrate applications
- Air shear technology is best suited for medium to sparse, smaller canopies, e.g. Vertical Shoot Position (VSP) vineyards

Horticultural vine and tree crops, as well as many vegetable crops, have canopies so dense and/or large that nozzles on their own can't achieve penetration. They need the help of air assist machinery. The role of the air is to open up the canopy and to carry the mainly VERY FINE to FINE spary quality further into the canopy. The larger the canopy the more air is needed.

CANOPY AIR DISPLACEMENT

The canopy air displacement theory for orchards and vineyards proposes that coverage in a canopy is optimised if all the volume of air within the canopy is replaced with spray loaded air produced by the sprayer (Figure 32d). While this is a somewhat loose concept, it is a helpful model to understand the limitations of spray equipment. Generally, the more m^3 the canopy accounts for the more m^3 need to be delivered by the sprayer.

This theoretical requirement highlights one of the potential pitfalls of applications in larger tree crops. Often the speed, driven by commercial machinery operators, does not reflect the canopy requirements for air displacement (Figure 32b, see Figure 33 for calculations).

For example, spraying both sides of a row in a 6 m high avocado orchard with a tree width of 4 m would require to produce 2400 m^3/100 m row. For an airblast machine that delivers 72,000 m^3/hour this would suggest a speed of 3 km/h. Most commercial applicators would probably drive around 5-6 km/h and therefore replace only 50-60% of the theoretical air volume. That implies that coverage in half of the canopy would rely on spray cloud drift or active droplet movement within the canopy. While this is not so much a problem in the lower parts of the canopy, the upper parts of a canopy could be

AIR DISPLACEMENT THEORY

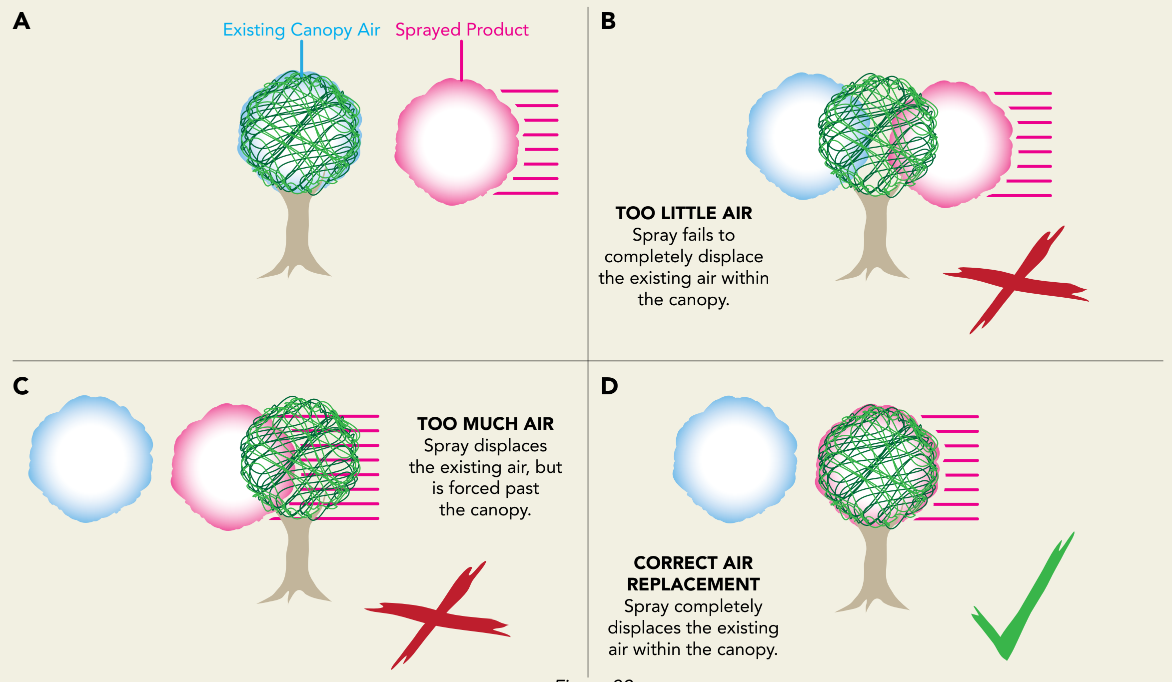


Figure 32

REAR MOUNTED AXIAL FAN OF AIRBLAST

Figure 34

ONE OF MANY NOZZLE MOUNTS ON AIRBLAST

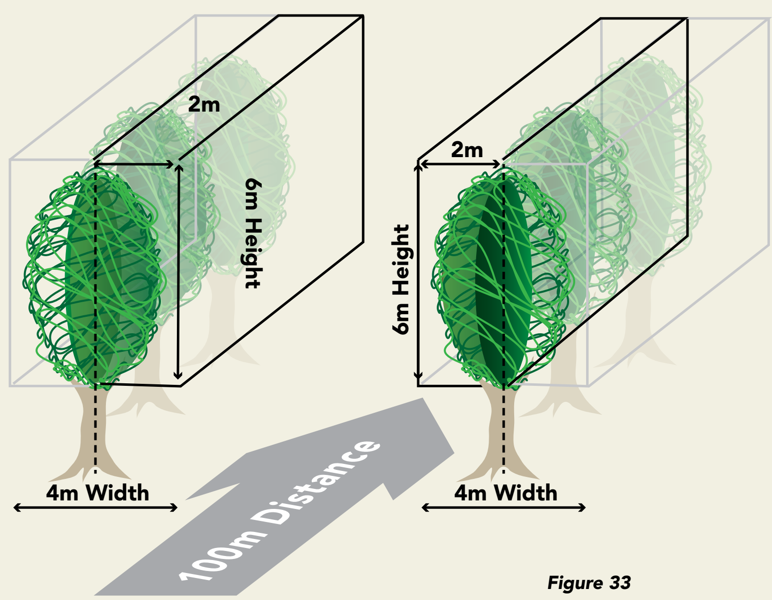
Figure 35

exposed to insufficient coverage. In situations where the actual produced air volume is much lower than the theoretical required volume, it is critical for the machinery to be able to deliver droplets up to the top of the canopy.

On the smaller end of canopy sizing, in crops with a smaller canopy size, for example grape vines applicators tend to produce too much air volume. For example a 1.5 m high, 1 m wide grape vine canopy would require 150 m^3 air/100 m row (see Figure 33 for calculations). An airblast sprayer in this situation, is likely to be driven at speeds around 8 km/h, producing 900 m^3/100 m row or six times more air than required. As a result spray plumes are often visibly high in the air and/or two rows down the track (Figure 32c). Yet, despite this excess on airflow, coverage is often not sufficient. This demonstrates an important further aspect of airflow, other than volume. It is air quality.

Different air assist machines deliver different air qualities. The quality of the air is best described by turbulence and velocity. Turbulent air is much better in opening up dense canopies by rattling leaves. Air with high-speed tends to tile leaves against each other, closing up canopy room rather than opening it. Very small droplets in turbulent air are swirling around and are likely to be deposited once they are within the canopy. Very small droplets in high-speed and high volume airstreams are more likely to follow the more straight airflow, are more easily blown out of the canopy and do not deposit as evenly on the back surface of leaves. While high velocity and high-volume airflow is not as efficient in opening up dense canopies it is better suited to travel longer distances.

EXAMPLE FOR AIR REPLACEMENT CALCULATIONS



Example for air replacement calculations for 6 m high trees and 4 m width with airblast machinery producing 72.000 m^3/hour

Theoretical requirement =
0.5 x 4 m x 6 m x 100 m x 2 = 2400 m^3/100m

- 0.5 = only air in one half of the tree needs to be replaced, the other half will be replaced when spraying the next row
- 4 x 6 m = height/width area of tree
- 100 m = distance unit
- 2 = both sides of the row are sprayed

The spray unit can produce 2400 m^3 30 times per hour (72.000 m^3/2400 m^3) and therefore travel 3 km in an hour (30 x 100 m) = 3 km/h

Example for air replacement calculations for 1.5 m high vines and 1 m width with airblast machinery producing 72.000 m^3/hour

Theoretical requirement =
0.5 x 1.5 m x 1 m x 100 m x 2 = 150 m^3/100 m

Figure 33

AIR ASSISTED MACHINERY

ONE OF MANY VALUTE VARIATIONS IN AIRBLAST

Figure 36

MACHINERY FOR VINE AND TREE SPRAYING

Several designs are on the market. Depending on crop type and layout they all have a fit in certain orchards and vineyards. The three most commonly found types are airblast, straight through axial fans and air shear sprayers.

Airblast Generally airblast sprayers have a rear mounted axial-fan (Figure 34). The larger the fan the larger the volume of air produced. Depending on the size of the PTO, tractor driven fans may range from 600 - 1000 mm. The Industry standard is around 900 mm and produces a massive airflow of 70 – 75,000 m^3/hour. Airblast sprayers with their own motor can drive even bigger fans and produce larger airflows. Other approaches to maximise the airflow are to use 2 fans or to direct all the air to a single-sided set-up. Airflow can be varied by around 20% by changing the pitch of the fan blades from 25 (minimum) - 35 (standard) and 45 (maximum). Changing the airflow has an impact on energy consumption. For example, a Croplands Cropliner requires 37 horsepower (hp) at the 35 setting but 51 hp at the 45 setting. Another way to vary airflow by 5-10% is to change the setting in the normally 2-speed fan gearbox from low to high.

The fan draws the air in and then blasts it out again in a narrow, vertical 160° semi circle past the nozzles. In its simplest version the nozzles are positioned around the circumference of the fan (Figure 35). The biggest advantage of this type of machinery is that it can be used in uneven terrain and in overgrown rows, e.g. almond crops. Standard airblast equipment is inexpensive. However, air control is limited and blasting air straight up in the sky makes them also prime candidates for drift concerns.

To have more influence on the direction of the spray and to create higher reach for taller crops, airblast machines are generally available with a range of valute options (Figures 36 & 37). With this set-up nozzles can be positioned closer to the target. The air has more direction and - depending on tower adjustment - drift potential can be greatly reduced.

Airblast machines have two major disadvantages. The first is efficiency. Drawing large amounts of air in and then turning it abruptly by 90° is energy consuming and inefficient. Running costs and hp requirements for airblast machines are high. The second disadvantage is that the large air volume is blasted out in a narrow band. In dense, highly moveable foliage, this is not the most productive approach to open up the canopy. In many situations it will result in leaves tiling together and acting as a barrier. For most crops airblast sprayers should not be used for concentrate spraying (see page 32).

ANOTHER VALUTE OPTION ON AIRBLAST

Figure 37

STRAIGHT THROUGH AXIAL FANS

Figure 38

AIR ASSISTED MACHINERY

CROPLANDS QUANTUM MIST™ ULTRA TOWER FOR MEDIUM TO TALL TREES

Figure 39

CROPLANDS QUANTUM MIST™ TOWER FOR MEDIUM TREES

Figure 40

Straight through axial fan The second most commonly used technology is a straight through axial fan such as a Croplands Quantum Mist™. These fans don't have to bend air. They simply suck it from behind to propel it out the front. These fans are generally much smaller than airblast fans. For example, in the Croplands Quantum Mist™ range they measure between 380 - 500 mm. Output is around 6,500 m^3/hour for the small head and 13,000 m^3/hour for the large head. Interlink produces a 900 mm fan. Depending on how many heads are used per row, the airflow is competitive with airblast machines. These fans are very versatile in their set-up and individual head positioning can be tailored to match the target canopy. They come as one-row, two-row or three-row machines for vine type crops (Figure 38) or in tower set-ups for tree crops (Figures 39 & Figure 40).

Quantum Mist™ type technology generally provides better coverage than airblast technology. The denser the crop, the more pronounced the results. The reason is the quality of airflow produced by the fans. The airflow is very turbulent and regarded as superior in opening up the canopy. The use of several heads allows the canopy to be approached from several angles.

Better efficiency in coverage compared to airblast machines generally allows a higher application speed and lower water volumes. Croplands Quantum Mist™ technology is versatile and can be used for dilute or concentrate spraying in dense or sparse, small or large crops. In tall crops, e.g. macadamia trees, the fans can be positioned closer to the top.

Air volume output can be regulated via fan speed within a 30% range. Differences in fan design between different commercially available products affects the quality of airflow.

Straight through axial fans are mainly driven via hydraulic pressure from the tractor oil supply. Oil requirements vary depending on the number of fans and the way they are linked. For example, a two-row grapevine sprayer with 8 x 500 mm fans needs an oil flow of 44 litre/min at the tractor remotes. Optional,

HYBRID SPRAYER

Figure 41

AIR ASSISTED MACHINERY

AIR SHEAR SPRAYER

Figure 42

AIR SHEAR SPRAYER

Figure 43

BARGAM SPRAYER

Figure 44

HORIZON SPRAYER

Figure 45

fully enclosed oil systems are available that allow to drive fans independently of tractor hydraulics. Horsepower requirements are negligible as a 500 mm fans needs only 2 hp. Compared to an airblast sprayer, running costs can be reduced by up to 30%. Croplands Quantum Mist™ fans are also available with cable drive technology which has even less hydraulic requirements and is quieter. Greentech fans are driven by electric motors. They are efficient too but their disadvantage is needing one electric motor per head. Only fully qualified electricians are allowed to service the system.

Hybrid sprayers A number of tree crop growers have built or upgraded their airblast sprayer with a two-head Croplnds Quantum Mist tower™ to get the best of both worlds (Figure 41). Two 500mm Croplands Quantum Mist™ heads increase the air capacity of an airblast sprayer by 30-40%. Their positioning dramatically increases the spray volume delivered to the top of the canopy. Depending on positioning of the heads, positive interaction between the two spray plumes can be achieved.

Air shear Air shear sprayers are designed for low water volume spraying only. Low volume of high-speed air pass jets that drip droplets into the airstream.

Several jets in several arms are set up per row (Figures 42 & 43). Like in airblast machines the air is produced in only narrow bands. The combination of low air volume, high speed and narrow band is generally not optimal for the opening up of canopies. Because of the low air output (approx 20,000 m^3/hour) the best option for air shear sprayers are small canopy crops, e.g. Vertical Shoot Position (VSP) vines.

AIR ASSIST IN VEGETABLES

Air assist spraying in vegetables is not as common as in vine and tree crops on canopies are not as large and dense. Droplets are released relatively close to the target and can be directed downwards via gravity and downward drift. In many situations this is sufficient to achieve an adequate level of coverage. However, there are many circumstances where the use of air assist is warranted to hit certain targets, e.g. the lower side of strawberry leaves.

Air curtain boom In vegetables, air assist most commonly comes from horizontal positioned axial fans that push air through a sleeve system along the boom, e.g. the Bargam systems (Figure 44). Air is released in a narrow curtain band passing the nozzles and facing downwards. As in an airblast sprayer, fans have to bend the air through a 90˚ angle to make it travel along the horizontal sleeve, then bend it again by 90˚ to direct the air downwards. This inefficient use of air results in low airflows. To increase airflow in larger booms tandem fans can be installed. The great benefit of Bargam type sprayers is their potentially wide boom span of up to 30 m for large area crops such as curcurbits or potatoes.

Straight through axial fans Croplands Quantum Mist™ fans are versatile and can be used facing downwards into crop (Figure 45). They provide far superior air than a curtain air boom. The number of fans that can be put in a row is currently limited to eight, resulting in a maximum span of 11 m covered.

POINTS TO CONSIDER WHEN CHOOSING A SPRAYER

Most points needing consideration in a purchasing decision are related to efficacy and efficiency, which ultimately translate into $ return. In a relatively easy to cover apple crop, the type of sprayer will not affect efficacy very much. However the right choice could greatly improve efficiency. In a difficult to cover crop, e.g. citrus, the type of sprayer will have a great influence on both efficacy and efficiency. Generally, the bigger the operation the more important efficiency becomes. The table below outlines some points that may need to be considered when choosing a sprayer.

COMPARISON BETWEEN DIFFERENT AIR ASSIST MACHINES

Costs	Considering both capital and running costs, how much can you afford?
	Does your budget allow for new or secondhand equipment?
	Could existing equipment be repaired or upgraded?
Crop or orchard design	Orchard Size
	Crop Density
	How important is it to optimise applications to control a particular pest or disease?
	Size of trees – how does the spray get to the top?
	Is the target crop robust (with only a few sprays per year) or sensitive (requiring ten or more sprays per year)?
	Is the crop pruned and easily accessible or overgrown?
	What is the terrain like – flat/even or sloping?
	How far will you be spraying from a water source? Is travel time an issue?
Drift	Is the crop close to sensitive areas such as susceptible crops, neighbours or an urban fringe?
	Is there a possibility that susceptible crops, neighbours or urban fringes may be an issue in the future?
Tractor requirements	Does your exiting tractor have enough horsepower and hydraulic flow capacity to power a new sprayer?
Service	Is there a good service network and technical backup available locally if needed?
Staff	Is the sprayer easy to use?
	Consider robustness of equipment.

		Airblast		Quantum Mist	Air Shear
		No Tower	Tower		
Air	Volume	High	High	High	Low
	Speed	High	High	Medium	Very High
	Turbulence	Low	Low	High	Very Low
	Overall Quality	Medium	Medium	Very Good	Low
Coverage	Sparse Canopies	Very Good	Very Good	Very Good	Very Good
	Medium Canopies	Good	Good	Very Good	Good
	Dense Canopies	Medium	Medium	Good	Medium
Application	Tractor Speed	Slow	Slow	Faster	Medium
	Water Volume	High	High	High to Low	Low
	Multiple Row	No/Some	No/Some	Yes	Yes
	Overall Efficiency	Medium	Medium	Good	Medium
	Row Obstacles	Good	Bad	Bad	Bad
	Versatility Set-Up	Medium	Good	Very Good	Good
	Uneven Terrain	Good	Medium	Medium	Medium
Environment	Noise	Loud	Loud	Medium	Loud
	Drift Potential	High	Medium	Medium	Medium
Costs	Running Costs	High	High	Good	Medium
	Purchase Costs	Low	Low	High	Medium
	Robustness	Excellent	Excellent	Very Good	Very Good

Figure 46

DILUTE SPRAYING

CHAPTER SUMMARY

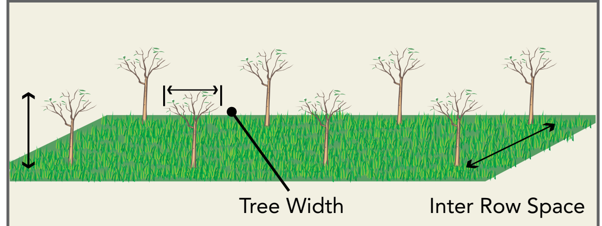
- The Dilute Spray Volume is needed to calculate the correct amount of chemical applied to the canopy
- It represents the maximum amount of spray mixture that can be applied to the canopy before reaching the point of run-off
- In combination with label concentration rate (mL or g/100 L) it is designed to achieve a satisfactory level of dose repetition in the field
- If available, the easiest starting point to determine a Dilute Volume is to refer to industry/local standards
- L/100 m row (Distanced Based Calibration) is the most user friendly unit for calibration (cross reference to L/ha or L/tree for sanity check)

Using the correct Dilute Spray Volume is fundamentally important for application. It provides the benchmark for calculationing of chemical rates applied to the canopy. A grower may actually never spray with the Dilute Volume but he needs to know what it is to apply the right amount of chemicals. Concepts like Tree Row Volume have been introduced to standardise the process, yet amongst many growers and advisors, Dilute Volume remains one of the greyest areas in the whole horticultural application process. This chapter deals with important definitions and the concept of Dilute Spray Volume which is simply to standardise the dose applied to a canopy and to minimise dose variation.

Canopy variation Any pesticide recommendation in horticultural tree and vine crops has to deal with a large variation of canopies. Trees have different heights, widths, foliage and planting densities (Figure 47). All of these factors influence the amount of chemical that needs to be applied to achieve efficacy. For example, a canopy in a vineyard with 2.8 m row spacing will need around 20% more spray volume compared to a similar canopy planted at 3.3 m row spacing simply because there are more rows to be sprayed. Trees with a canopy height of 4 m will need roughly double the amount of spray liquid compared with their 2 m counterparts.

A two dimensional per ha rate can only loosely relate to three dimensional targets. In Australia the industry has moved away from the two dimensional per/ha label rate. Instead, all label rates for horticultural tree and vine pesticides are expressed in product per 100 L of spray volume. Older products may still have an additional per ha rate on the label. Products for vegetables have both a per 100 L and a per hectare rate.

THREE DIMENSIONAL FACTORS AFFECTING SPRAY VOLUME



- Density
- (Tree shape)
- Row spacing
- Height

Figure 47

Concentration Prescribing a rate /100 L of water assures that chemicals are always applied at a precise concentration, e.g. 140 g of Nufarm Champ®/100 L. The /100 L label rate guarantees that growers use exactly the same concentration researchers worked with to achieve registration.

Dose Mixing up the right concentration is only half the story. It is equally important to determine the water volume needed to cover the crop. The combination of correct water volume and correct concentration achieves the correct dose; the desirable amount of chemical per leaf area.

A grower applying 1000 L/ha uses 1.4 kg Nufarm Champ®/ha (10 x 140 g/100 L). Another grower with a similar dimensioned orchard uses 1500 L/ha - 2.1 kg Nufarm Champ®/ha. The second grower applies 50% more fungicide to the canopy. While the Australian label assures the product is put out at the right concentration, it assumes that a grower is able to apply the same amount of spray solution on to the leaf as the researcher did when they established efficacy. So, which of the two growers got it right? Is the second grower wasting chemical and money or is the first grower not putting enough chemical on? The answer depends on who of the two is closest to the Dilute Volume.

DILUTE SPRAYING

DILUTE VOLUME

It is difficult to produce a standard for spray solution volumes than can be replicated in different crops and locations. To create a replicable standard and minimise dosage variation, researchers aim to determine the Dilute Volume. Dilute Volume is the maximum amount of spray solution on a leaf before reaching the point of run-off. Point of run-off is not a perfect solution, but provides the closest practical estimate.

Dilute Volume is often established using a MEDIUM to COARSE spray quality. However, most commercially available spray equipment – such as Quantum Mist – generally produce FINE droplets and can reach the point of run-off at a lower volume than the true Dilute Volume. As an applicator, this is important. The aim is to replicate the way the researcher established efficacy.

Good coverage – as indicated by visual indicators such as water sensitive paper or dyes – should not be confused with the Dilute Volume. Modern sprayers are able to achieve satisfactory coverage with lower water volumes. Thinly, well-covered surfaces may be able to be loaded with more solution (i.e an increased dose) before reaching the point of run-off.

Point of run-off Point of run-off is defined as the maximum amount of spray volume applied on the target surface before the solution is forced to run-off. The point of run-off occurs when gravity overcomes surface tension and spray droplets begin to roll of the leaf. Spraying up to the point of run-off will achieve the maximum deposition for a sprayer.

POINT OF RUN-OFF

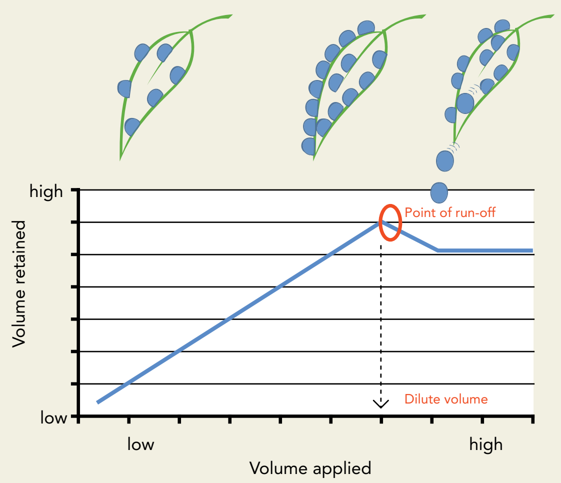


Figure 48

Spraying beyond this point generally results in a reduction in dosage (or wastage) as excess solution cannot be held on the leaf surface once surface tension is broken.

The point of run-off does not automatically define a Dilute Spray Volume – unless MEDIUM to COARSE droplets are used in conjunction with a sprayer designed for high volume applications (e.g. an airblast machine) to allow the maximum deposition of spray. The point of run-off may occur at different spray volumes for different types of sprayers.

The term 'point of run-off' infers that there is an exact volume of solution that a leaf surface is capable of retaining. Realistically, an applicator is unlikely to reach this volume as coverage across a canopy is uneven. The outside of a canopy is more easily saturated than the inner and as such, researchers generally accept a level of even coverage in the inner canopy while the outer canopy is saturated when determining the point of run-off. Determining the point of run-off in the field relies on an individual's judgment, which in return involves variation and errors.

Fortunately label rates are generally robust and it is usually sufficient to be within +/- 15% of the Dilute Volume – at this level coverage and dose loading variation should be within acceptable levels.

FLOODING AND UNDERDOSING

Flooding Using a spray volume above the point of run-off results in increased run-off. In many cases it is a waste of time and money (Figure 49d). However, some miticides and some Point Growth Regulations (PGRs) may benefit from running down from parts of the plant. With this approach it is important to closely follow the Dilute Volume concentration recommended on the label.

Underdosing occurs when the spray volume is significantly below the Dilute Volume, without the per 100L rate being increased (figure 49b). The applicator is using the right concentration but not putting enough volume on to achieve the correct dose. This may reduce efficacy – or worse – result in a sublethal dose that has the potential to accelerate resistance development.

DILUTE SPRAYING

DETERMINING THE DILUTE VOLUME

There are several ways to determine the Dilute Volume, refer to industry guidelines, use local standards, do your own testing or use the Spraywise dilute chart. A sensible approach is to use all the information available, and put them to test while setting up the equipment.

Industry guidelines Most horticultural industries have made efforts to establish their own guidelines for determining Dilute Volume. Dilute Volumes will vary with different leaf and fruit surfaces, tree shape and sizes, canopy density and spacing. Unfortunately the recommended volumes in these guidelines can vary greatly, depending on the research approach. Different researchers use different methods and units to describe the Dilute Volume (see pages 30 - 31). Most of the research uses some form of canopy volumes approaches, such as Tree Row Volume, as the base to establish dilute volumes. The principle is that larger canopies will need more spray volume to be wetted than smaller canopies.

Spraywise Dilute is a very user friendly and recommended version for determining the Dilute Volume for all major crops. (see page 27).

Local standards Local standards for Dilute Volumes were established on the basis of providing a satisfactory level of control. They may be identical to industry standards. In other cases they may vary from industry standards because of factors such as lower or higher local pest and disease pressure or unusual local canopies. Be aware of them and take them into consideration.

Testing for Dilute Volume In principle, the procedure for testing for the Dilute Volume is similar to setting up a sprayer (see page 57). However, many growers will not be able to test directly for the Dilute Volume because their machinery is not suitable to fulfill all definitions (designed for high volume application, MEDIUM to COARSE droplets). Sophisticated machinery such as a Croplands Quantum Mist is able to reach sufficient coverage and possibly the point of run-off at 70-80% of the true Dilute Volume achieved with an e.g. airblast. For low volume machines, the Dilute Volume is only a benchmark for calculating of chemical rates. In most cases, the actual application volume will be a concentrate spray (see page 32).

RELATIONSHIP BETWEEN CONCENTRATION AND SPRAYVOLUME = DOSE

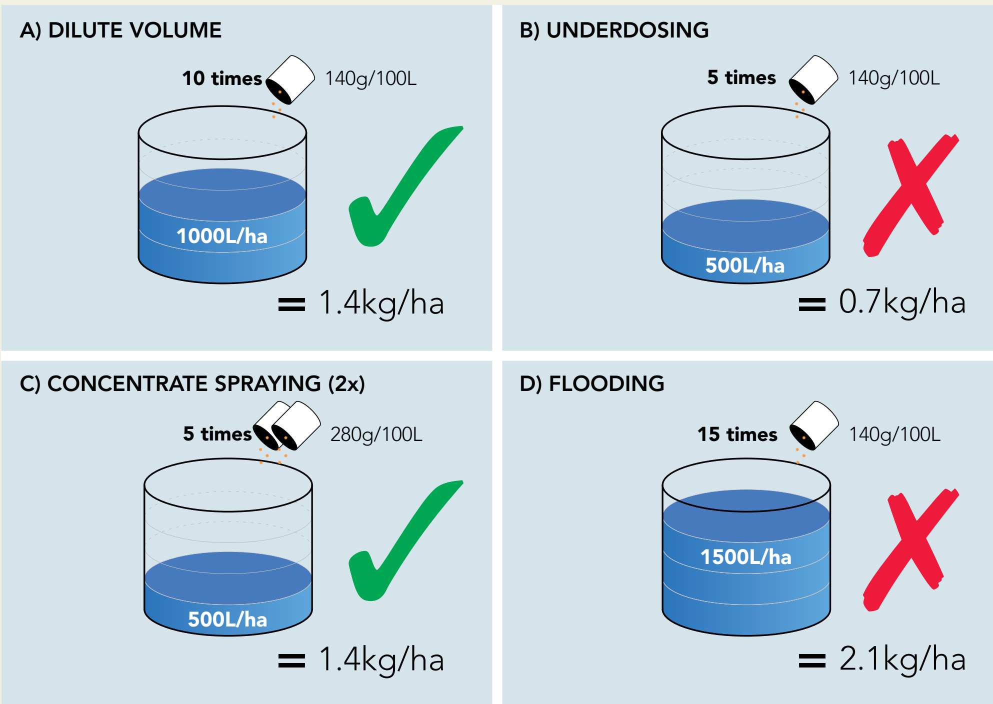


Figure 49 *Example for a 1000 L/ha Dilute Volume, label rate Nufarm Champ® 140 g/ha*

DILUTE SPRAYING

USING THE SPRAYWISE DILUTE CHART

The Spraywise dilute chart (Figure 51) makes application easy. It works on the principle that for most horticultural tree and vine crops there is very strong correllation between Dilute Volume and canopy height. For most crops the Dilute Volume can be expressed as 20 L/100 m per m height at full canopy. For every 100 m the machine travels along the row it needs to deliver 20 L per m canopy height. Expressing the volume over a 100 m distance is also known as Distanced Based Calibration.

All a grower has to do is to measure the height of the tree/vine canopy. For example, a 2 m tall full apple canopy will need 40 L/100 m, a 4 m high canopy will need 80 L/100 m. A 7 m high mango canopy will need 140 L/100 m. It is as simple as that! The Spraywise dilute chart allows also to work with slightly higher volumes to allow for denser canopies, for example Riverland vine canopies compared to VSP canopies.

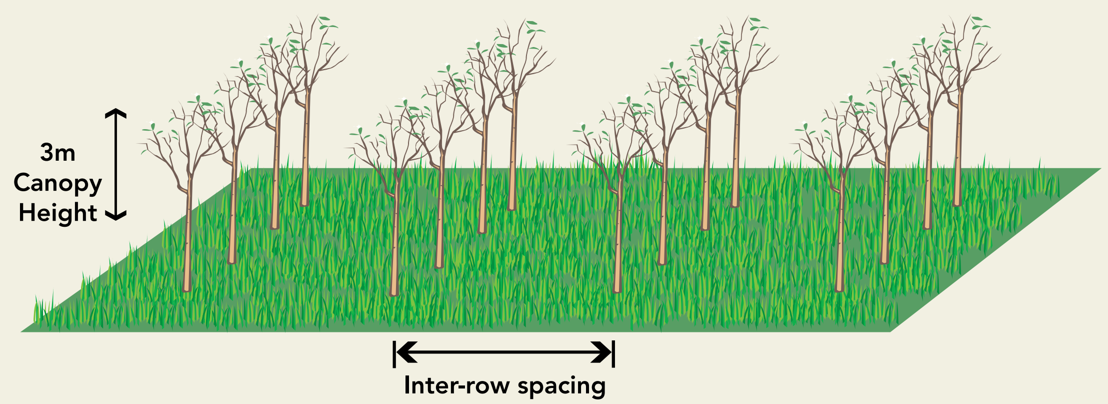
Distanced Based Calibration assumes the sprayer is set up to cover the canopy. If the sprayer is covering more or less than the actual size of the canopy the Dilute Volume for the sprayed target becomes the covering spray width of the equipment.

Even though this is the easiest method for working out the Dilute Volume, most growers would be unfamiliar with the per 100 m concept. It is advisable to do a sanity check by refering the volume back to a more familiar per ha or per tree volume (Figures 52 & 55). The 4 m high apple tree is likely to grow on 4 m row spacing = 2000 L/ha. The mango tree from our example is more likely to grow on 9 m row spacing = 1500 L/ha. While the L/100 values is based on the height of the tree (80 L vs 140 L/100 m in our example), the L/ha volume is influenced by row spacing.

EXAMPLE

An agronomist in a Yarra Valley vineyard recommends the local standard of 1000 L/ha (or 28 L/100 m at 2.8 m row spacing) as Dilute Volume for a full VSP canopy (lets say 1.2 m height x 0.75 m width). Using the Spraywise dilute chart the Dilute Volume would be 24 L/100 m or 870 L/ha). According to the South Australian Research and Development Institution (SARDI) industry standard the Dilute Volume for this kind of canopy should be in the vicinity of 25 L/100 m (or 900 L/ha at 2.8 m row spacing). Using a Croplands Quantum Mist™ the grower achieves good coverage in the inner canopy at 700 L/ha (or 20 L/100 m). He estimates that in his VSP canopy his machinery may reach this coverage at around 70–80% of the true Dilute Volume = 875 - 1000 L/ha (or 24-28 L/100m). Using all three approaches, the grower can be confident of being fairly close to the true Dilute Volume using 900 L/ha (or 25 L/100 m) as the benchmark for his chemical rate calculations.

IMPORTANCE OF INTER-ROW SPACING FOR SPRAY VOLUME



Example		
Inter-row spacing	Distance to drive to cover / ha	Dilute Volume (based on 20 L/100 m per m height)
3 m	3333 m	2000 L/ha
4 m	2500 m	1500 L/ha
5 m	2000 m	1200 L/ha

Figure 50

DILUTE SPRAYING

HOW TO MEASURE A TALL TREE CANOPY

The easiest way to measure the exact canopy height of a tall tree is to walk some distance away from the tree. Take a long pencil or stick in your fingers and along your extended arm compare the height of the canopy with the length of the pencil. Walk forward or backwards until the length of the pencil matches the height of the canopy. Tilt the pencil horizontal with one end in line with the base of the trunk. Mark or remember the spot the tip is pointing at. Measure along the ground the distance between trunk and point. This is the same as the height of the canopy.

TRANSFERRING L/100 M INTO L/HA OR L PER TREE

It is handy to translate a L/100 m value into a L/ha value (sanity check, cost calculations). A L/100 m value is related to the L/ha value simply by row spacing. Figure 52 can be used to transform L/100 m quickly into L/ha. For example, 20 L/100 m at a row spacing of 2.5 m equates to 800 L/ha (Figure 53). The same can be done to calculate L per tree values. Simply take the L per 100 m value and compare it with tree spacing along the row. For example, a 150 L/100m row volume for trees that are spaced 3 m apart along the row equates to 4.5 L/tree (Figures 54 & 55).

It is easier to work with Distance Based Calibration, than area based calibration because it takes row variation out of the calculation (Figure 50). When using this method, a grape grower who changes from a block with 3.3 m row spacing to a block with 2.7 m row spacing is not required to change anything if the canopies have similar heights. The per 100 m volume remains the same. The per hectare value will change automatically. An apple grower who swaps from a 3 m high canopy block to a 4 m high canopy block simply changes the volume from 60 L per 100 m to 80 L per 100 m.

It may seem strange that the same volume of 20 L/100 m per m height can be applied to very different crops. A 5 m wide mango tree must surely demand a different volume to a grapevine?

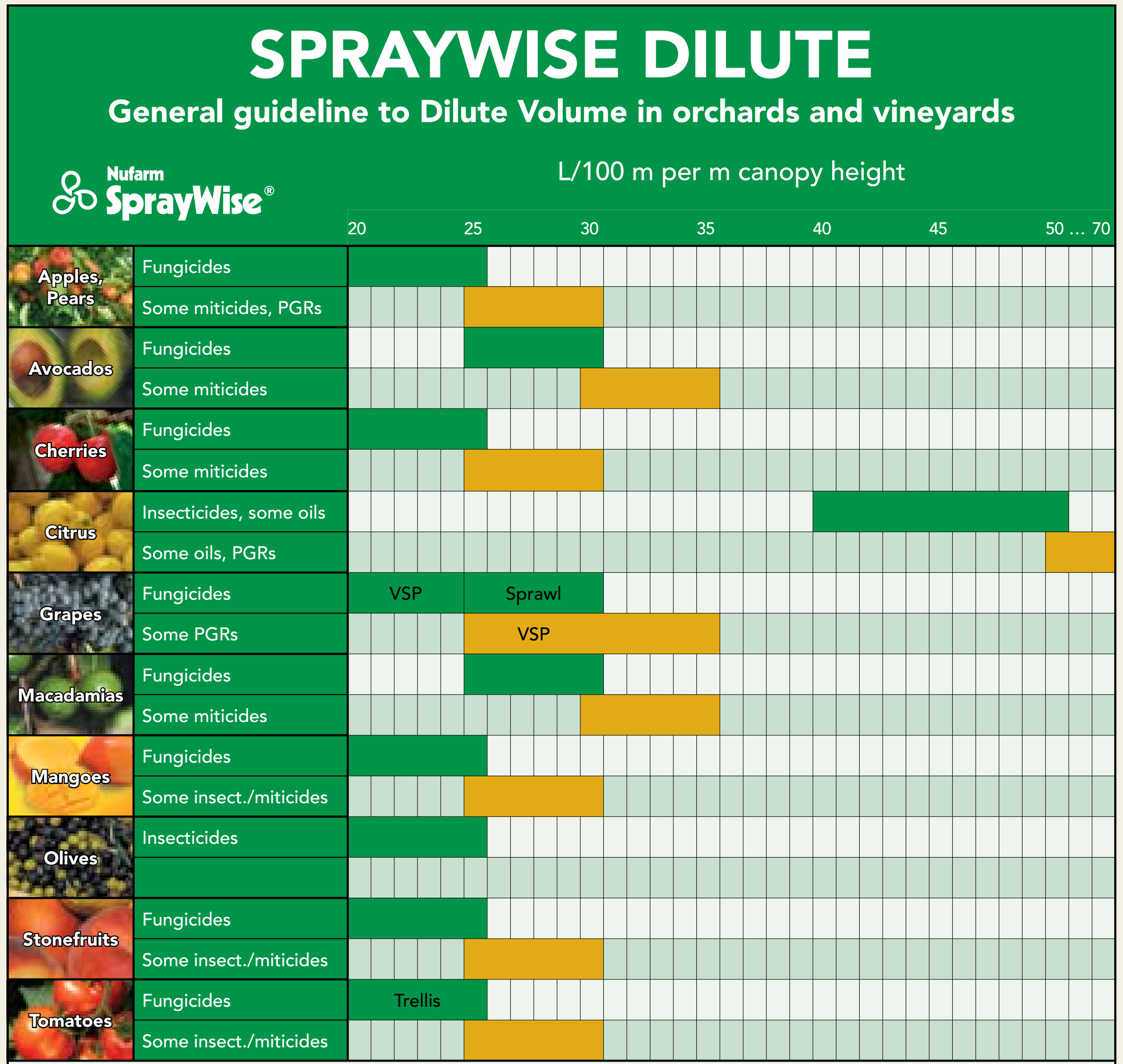
A grape vine canopy, may be 80–100 cm wide, can be dense and leaves tile easily. In comparison, the mango tree may have a 50 cm wide outer leaf canopy, followed by a 4 m wide fairly leaf less inner canopy, followed by another 50 cm wide outer canopy. The difference between actual leaf areas over a meter height is not that great. A 2 m wide apple tree has leaves all through the canopy, but the apple canopy is not very dense. Research has shown that the 20 L/100 m per m height is a remarkably robust volume to describe the Dilute Volume for many crops. Some crops with significantly denser canopies, like avocados and macadamias need a higher value. For citrus crops the volume needs to be doubled to at least 40 L/100 m per m height (Figure 51).

DECIDUOUS TREE AND VINE CROPS

Many tree and vine crops change leaf density throughout the season demanding different spray volumes. The 20 L/100 m value is for full canopies only. An apple tree at budburst needs only 70% of that (Figure 51). That may sound a lot given there is only 1% of foliage compared to a full canopy. However the sprayer still needs to cover the space to deliver the right dose to the small targets. For example, a Croplsnds Quantum Mist™ head will cover approximately 1 m height. It cannot cover less, even if vine shoots are only 10 cm long. To get the right dose on the small target, a lot of product has to be wasted into empty space.

DILUTE SPRAYING

SPRAYWISE DILUTE



= indicates Dilute Volume, sprayed to the point of run-off

= indicates light flood Volume, above the point of run-off (some miticides, insecticides and PGRs may benefit)

Example: A 3 m high apple canopy should need a dilute rate between 60 - 75 L /100 m (3 x 20 or 3 x 25). As a sanity check, at a row spacing of 4 m that converts to 1500 - 1900 L/ha (see table next page). If not sure which way to go, as a sophisticated guess, the middle should be close, e.g. 70 L/100 m.

IMPORTANT:

- Volumes are given for full canopy
- Volumes may vary according to canopy type, e.g. VSP vs Sprawl, shape and density. Use the lower end of the spectrum for easier to cover targets, e.g in grapes use 20–25 for VSP and 25–30 for Sprawl
- Height considers canopy height only - excluding the trunk
- Guidelines assume that the sprayer is set up to cover the canopy height. In early season grapevine applications the minimum sprayer width becomes the canopy height! For example, a Croplands Quantum Mist™ head covers 1 m. It can not be reduced to cover 10 cm shoots only. Therefore the Dilute Volume has to operate on the minimum width the equipment can produce

RATE FOR EARLY SEASON APPLICATIONS IN DECIDUOUS TREE/VINE CROPS
(in L/100 m per m Canopy Height)

Budburst	1st Spray BB+10 days	2nd Spray BB+20 days	3rd Spray BB+30 days
14L (70 % of 20 L)	16L (80% of 20 L)	18L (90% of 20 L)	Full rate

Figure 51

DILUTE SPRAYING

HEADING

L/ha ⟷ L/100 m — Table unit = L/100 m

Row spacing (m)

L/ha	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
100	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
150	2.4	2.7	3	3.1	3.6	3.8	4	4.2	4.4	4.5	4.7	4.8	5	5.3	5.4	6	6.8	7.5	8.3	9	9.8	10.5	11.3	12	12.8	13.5	15
200	3.2	3.6	4	4.2	4.8	5	5.4	5.6	5.8	6	6.2	6.4	6.7	7	7.2	8	9	10	11	12	13	14	15	16	17	18	20
250	4	4.5	5	5.2	6	6.3	6.7	7	7.3	7.5	7.8	8	8.3	8.8	9.0	10	11.3	12.5	13.8	15	16.3	17.5	18.8	20	21	23	25
300	4.8	5.4	6	6.3	7.1	7.5	8.1	8.4	8.7	9	9.3	9.6	10	10.5	10.8	12	13.5	15	16.5	18	19.5	21	23	24	26	27	30
350	5.6	6.3	7	7.3	8.3	8.8	9.4	9.8	10.2	10.5	10.9	11.2	11.7	12.3	12.6	14	15.8	17.5	19.3	21	23	25	26	28	30	32	35
400	6.4	7.2	8	8.3	9.5	10	10.8	11.2	11.6	12	12.4	12.8	13.3	14	14.4	16	18	20	22	24	26	28	30	32	34	36	40
450	7.2	8.1	9	9.4	11	11.3	12.1	12.6	13.1	13.5	14	14.4	15	15.8	16.2	18	20	23	25	27	29	32	34	36	38	41	45
500	8	9	10	10	12	12.5	13.5	14	14.5	15	15.5	16	16.7	17.5	18	20	23	25	28	30	33	35	38	40	43	45	50
600	9.6	10.8	12	13	14	15	16.2	16.8	17.4	18	18.6	19.2	20	21	22	24	27	30	33	36	39	42	45	48	51	54	60
700	11.2	12.6	14	15	17	17.5	18.9	19.6	20	21	22	22	23	25	25	28	32	35	39	42	46	49	53	56	60	63	70
750	12	13.5	15	16	18	18.8	20	21	22	23	23	24	25	26	27	30	34	38	41	45	49	53	56	60	64	68	75
800	12.8	14.4	16	17	19	20	22	22	23	24	25	26	27	28	29	32	36	40	44	48	52	56	60	64	68	72	80
900	14.4	16.2	18	19	21	23	24	25	26	27	28	29	30	32	32	36	41	45	50	54	59	63	68	72	77	81	90
1000	16	18	20	21	24	25	27	28	29	30	31	32	33	35	36	40	45	50	55	60	65	70	75	80	85	90	100
1100	17.6	19.8	22	23	26	28	30	31	32	33	34	35	37	39	40	44	50	55	61	66	72	77	83	88	94	99	110
1200	19.2	22	24	25	29	30	32	34	35	36	37	38	40	42	43	48	54	60	66	72	78	84	90	96	102	108	120
1300	21	23	26	27	31	33	35	36	38	39	40	42	43	46	47	52	59	65	72	78	85	91	98	104	111	117	130
1400	22	25	28	29	33	35	38	39	41	42	43	45	47	49	50	56	63	70	77	84	91	98	105	112	119	126	140
1500	24	27	30	31	36	38	40	42	44	45	47	48	50	53	54	60	68	75	83	90	98	105	113	120	128	135	150
1600	26	29	32	33	38	40	43	45	46	48	50	51	53	56	58	64	72	80	88	96	104	112	120	128	136	144	160
1700	27	31	34	35	40	43	46	48	49	51	53	54	57	60	61	68	77	85	94	102	111	119	128	136	145	153	170
1800	29	32	36	38	43	45	49	50	52	54	56	58	60	63	65	72	81	90	99	108	117	126	135	144	153	162	180
1900	30	34	38	40	45	48	51	53	55	57	59	61	63	67	68	76	86	95	105	114	124	133	143	152	162	171	190
2000	32	36	40	42	48	50	54	56	58	60	62	64	67	70	72	80	90	100	110	120	130	140	150	160	170	180	200
2500	40	45	50	52	60	63	67	70	73	75	78	80	83	88	90	100	113	125	138	150	163	175	188	200	213	225	250
3000	48	54	60	63	71	75	81	84	87	90	93	96	100	105	108	120	135	150	165	180	195	210	225	240	255	270	300
4000	64	72	80	83	95	100	108	112	116	120	124	128	133	140	144	160	180	200	220	240	260	280	300	320	340	360	400
5000	80	90	100	104	119	125	135	140	145	150	155	160	167	175	180	200	225	250	275	300	325	350	375	400	425	450	500
6000	96	108	120	125	143	150	162	168	174	180	186	192	200	210	216	240	270	300	330	360	390	420	450	480	510	540	600
7000	112	126	140	146	167	175	189	196	203	210	217	224	233	245	252	280	315	350	385	420	455	490	525	560	595	630	700
8000	128	144	160	167	190	200	216	224	232	240	248	256	266	280	288	320	360	400	440	480	520	560	600	640	680	720	800
9000	144	162	180	188	214	225	243	252	261	270	279	288	300	315	324	360	405	450	495	540	585	630	675	720	765	810	900
10000	160	180	200	208	238	250	270	280	290	300	310	320	333	350	360	400	450	500	550	600	650	700	750	800	850	900	1000
Conversion Factor	62.5	55.5	50	47.6	41.7	40	37.0	35.7	34.5	33.3	32.3	31.3	30.3	28.6	27.8	25	22.2	20	18.2	16.7	15.4	14.3	13.3	12.5	11.8	11.1	10

Formula: L/100 m = L/ha ÷ 100 x row spacing (m) L/ha = L/100 m x 100 ÷ row spacing (m)

Figure 52

HEADING

L/ha ⟷ L/100 m — Table unit = L/100 m

Row spacing (m)

L/ha	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
100	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
150	2.4	2.7	3	3.1	3.6	3.8	4	4.2	4.4	4.5	4.7	4.8	5	5.3	5.4	6	6.8	7.5	8.3	9	9.8	10.5	11.3	12	12.8	13.5	15
200	3.2	3.6	4	4.2	4.8	5	5.4	5.6	5.8	6	6.2	6.4	6.7	7	7.2	8	9	10	11	12	13	14	15	16	17	18	20
250	4	4.5	5	5.2	6	6.3	6.7	7	7.3	7.5	7.8	8	8.3	8.8	9.0	10	11.3	12.5	13.8	15	16.3	17.5	18.8	20	21	23	25
300	4.8	5.4	6	6.3	7.1	7.5	8.1	8.4	8.7	9	9.3	9.6	10	10.5	10.8	12	13.5	15	16.5	18	19.5	21	23	24	26	27	30
350	5.6	6.3	7	7.3	8.3	8.8	9.4	9.8	10.2	10.5	10.9	11.2	11.7	12.3	12.6	14	15.8	17.5	19.3	21	23	25	26	28	30	32	35
400	6.4	7.2	8	8.3	9.5	10	10.8	11.2	11.6	12	12.4	12.8	13.3	14	14.4	16	18	20	22	24	26	28	30	32	34	36	40
450	7.2	8.1	9	9.4	11	11.3	12.1	12.6	13.1	13.5	14	14.4	15	15.8	16.2	18	20	23	25	27	29	32	34	36	38	41	45
500	8	9	10	10	12	12.5	13.5	14	14.5	15	15.5	16	16.7	17.5	18	20	23	25	28	30	33	35	38	40	43	45	50
600	9.6	10.8	12	13	14	15	16.2	16.8	17.4	18	18.6	19.2	20	21	22	24	27	30	33	36	39	42	45	48	51	54	60
700	11.2	12.6	14	15	17	17.5	18.9	19.6	20	21	22	22	23	25	25	28	32	35	39	42	46	49	53	56	60	63	70
750	12	13.5	15	16	18	18.8	20	21	22	23	23	24	25	26	27	30	34	38	41	45	49	53	56	60	64	68	75
800	12.8	14.4	16	17	19	20	22	22	23	24	25	26	27	28	29	32	36	40	44	48	52	56	60	64	68	72	80
900	14.4	16.2	18	19	21	23	24	25	26	27	28	29	30	32	32	36	41	45	50	54	59	63	68	72	77	81	90
1000	16	18	20	21	24	25	27	28	29	30	31	32	33	35	36	40	45	50	55	60	65	70	75	80	85	90	100
1100	17.6	19.8	22	23	26	28	30	31	32	33	34	35	37	39	40	44	50	55	61	66	72	77	83	88	94	99	110
1200	19.2	22	24	25	29	30	32	34	35	36	37	38	40	42	43	48	54	60	66	72	78	84	90	96	102	108	120
1300	21	23	26	27	31	33	35	36	38	39	40	42	43	46	47	52	59	65	72	78	85	91	98	104	111	117	130
1400	22	25	28	29	33	35	38	39	41	42	43	45	47	49	50	56	63	70	77	84	91	98	105	112	119	126	140
1500	24	27	30	31	36	38	40	42	44	45	47	48	50	53	54	60	68	75	83	90	98	105	113	120	128	135	150
1600	26	29	32	33	38	40	43	45	46	48	50	51	53	56	58	64	72	80	88	96	104	112	120	128	136	144	160
1700	27	31	34	35	40	43	46	48	49	51	53	54	57	60	61	68	77	85	94	102	111	119	128	136	145	153	170
1800	29	32	36	38	43	45	49	50	52	54	56	58	60	63	65	72	81	90	99	108	117	126	135	144	153	162	180
1900	30	34	38	40	45	48	51	53	55	57	59	61	63	67	68	76	86	95	105	114	124	133	143	152	162	171	190
2000	32	36	40	42	48	50	54	56	58	60	62	64	67	70	72	80	90	100	110	120	130	140	150	160	170	180	200
2500	40	45	50	52	60	63	67	70	73	75	78	80	83	88	90	100	113	125	138	150	163	175	188	200	213	225	250
3000	48	54	60	63	71	75	81	84	87	90	93	96	100	105	108	120	135	150	165	180	195	210	225	240	255	270	300
4000	64	72	80	83	95	100	108	112	116	120	124	128	133	140	144	160	180	200	220	240	260	280	300	320	340	360	400
5000	80	90	100	104	119	125	135	140	145	150	155	160	167	175	180	200	225	250	275	300	325	350	375	400	425	450	500
6000	96	108	120	125	143	150	162	168	174	180	186	192	200	210	216	240	270	300	330	360	390	420	450	480	510	540	600
7000	112	126	140	146	167	175	189	196	203	210	217	224	233	245	252	280	315	350	385	420	455	490	525	560	595	630	700
8000	128	144	160	167	190	200	216	224	232	240	248	256	266	280	288	320	360	400	440	480	520	560	600	640	680	720	800
9000	144	162	180	188	214	225	243	252	261	270	279	288	300	315	324	360	405	450	495	540	585	630	675	720	765	810	900
10000	160	180	200	208	238	250	270	280	290	300	310	320	333	350	360	400	450	500	550	600	650	700	750	800	850	900	1000
Conversion Factor	62.5	55.5	50	47.6	41.7	40	37.0	35.7	34.5	33.3	32.3	31.3	30.3	28.6	27.8	25	22.2	20	18.2	16.7	15.4	14.3	13.3	12.5	11.8	11.1	10

Formula: L/100 m = L/ha ÷ 100 x row spacing (m) L/ha = L/100 m x 100 ÷ row spacing (m)

Figure 53

DILUTE SPRAYING

HEADING

L/tree ⟷ L/100 m — Table unit = L/100 m

Tree spacing along Row (m)

L/tree	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
0.5	31	28	25	24	21	20	19	18	17	17	16	16	15	14	14	13	11	10	9	8	8	7	7	6.3	5.9	5.6	5
1	63	56	50	48	42	40	37	36	35	33	32	31	30	29	28	25	22	20	18.2	17	15.4	14	13.3	12.5	11.8	11	10
1.5	94	83	75	72	63	60	56	54	52	50	48	47	45	43	42	38	33	30	27	25	23	21	20	18.8	17.7	16.7	15
2	125	111	100	96	84	80	74	71	69	67	65	63	61	57	56	50	44	40	36	33	31	29	27	25	24	22	20
2.5	156	139	125	120	105	100	93	89	86	83	81	78	76	72	70	63	56	50	46	42	39	36	33	31	30	28	25
3	188	167	150	144	126	120	111	107	104	100	97	94	91	86	83	75	67	60	55	50	46	43	40	38	35	33	30
3.5	219	194	175	168	147	140	130	125	121	117	113	110	106	100	97	88	78	70	64	58	54	50	47	44	41	39	35
4	250	222	200	192	168	160	148	143	138	133	129	125	121	114	111	100	89	80	73	67	62	57	53	50	47	44	40
4.5	281	250	225	216	189	180	167	161	155	150	145	141	136	129	125	113	100	90	82	75	69	64	60	56	53	50	45
5	313	278	250	240	210	200	185	179	173	167	162	157	152	143	139	125	111	100	91	84	77	72	67	63	59	56	50
5.5	344	305	275	264	231	220	204	196	190	183	178	172	167	157	153	138	122	110	100	92	85	79	73	69	65	61	55
6	375	333	300	288	252	240	222	214	207	200	194	188	182	172	167	150	133	120	109	100	92	86	80	75	71	67	60
6.5	406	361	325	312	273	260	241	232	224	216	210	203	197	186	181	163	144	130	118	109	100	93	86	81	77	72	65
7	438	389	350	336	294	280	259	250	242	233	226	219	212	200	195	175	155	140	127	117	108	100	93	88	83	78	70
7.5	469	416	375	360	315	300	278	268	259	250	242	235	227	215	209	188	167	150	137	125	116	107	100	94	89	83	75
8	500	444	400	384	336	320	296	286	276	266	258	250	242	229	222	200	178	160	146	134	123	114	106	100	94	89	80
8.5	531	472	425	408	357	340	315	303	293	283	275	266	258	243	236	213	189	170	155	142	131	122	113	106	100	94	85
9	563	500	450	432	378	360	333	321	311	300	291	282	273	257	250	225	200	180	164	150	139	129	120	113	106	100	90
9.5	594	527	475	456	399	380	352	339	328	316	307	297	288	272	264	238	211	190	173	159	146	136	126	119	112	105	95
10	625	555	500	480	420	400	370	357	345	333	323	313	303	286	278	250	222	200	182	167	154	143	133	125	118	111	100
10.5	656	583	525	504	441	420	389	375	362	350	339	329	318	300	292	263	233	210	191	175	162	150	140	131	124	117	105
11	688	611	550	528	462	440	407	393	380	366	355	344	333	315	306	275	244	220	200	184	169	157	146	138	130	122	110
11.5	719	638	575	552	483	460	426	411	397	383	371	360	348	329	320	288	255	230	209	192	177	164	153	144	136	128	115
12	750	666	600	576	504	480	444	428	414	400	388	376	364	343	334	300	266	240	218	200	185	172	160	150	142	133	120
12.5	781	694	625	600	525	500	463	446	431	416	404	391	379	358	348	313	278	250	228	209	193	179	166	156	148	139	125
13	813	722	650	624	546	520	481	464	449	433	420	407	394	372	361	325	289	260	237	217	200	186	173	163	153	144	130
14	875	777	700	672	588	560	518	500	483	466	452	438	424	400	389	350	311	280	255	234	216	200	186	175	165	155	140
Conversion Factor	62.5	55.5	50	47.6	41.7	40	37.0	35.7	34.5	33.3	32.3	31.3	30.3	28.6	27.8	25	22.2	20	18.2	16.7	15.4	14.3	13.3	12.5	11.8	11.1	10

Formula: L/tree = L/100 m ÷ 100 x tree spacing (m) L/100 m = L/tree x 100 ÷ tree spacing (m)

Note: This table and formula treat the tree row as a continuous hedge (regardless of actual tree width) as most sprayers can not distinguish between canopy and empty space.

Figure 54

HEADING

L/tree ⟷ L/100 m — Table unit = L/100 m

Tree spacing along Row (m)

L/tree	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
0.5	31	28	25	24	21	20	19	18	17	17	16	16	15	14	14	13	11	10	9	8	8	7	7	6.3	5.9	5.6	5
1	63	56	50	48	42	40	37	36	35	33	32	31	30	29	28	25	22	20	18.2	17	15.4	14	13.3	12.5	11.8	11	10
1.5	94	83	75	72	63	60	56	54	52	50	48	47	45	43	42	38	33	30	27	25	23	21	20	18.8	17.7	16.7	15
2	125	111	100	96	84	80	74	71	69	67	65	63	61	57	56	50	44	40	36	33	31	29	27	25	24	22	20
2.5	156	139	125	120	105	100	93	89	86	83	81	78	76	72	70	63	56	50	46	42	39	36	33	31	30	28	25
3	188	167	150	144	126	120	111	107	104	100	97	94	91	86	83	75	67	60	55	50	46	43	40	38	35	33	30
3.5	219	194	175	168	147	140	130	125	121	117	113	110	106	100	97	88	78	70	64	58	54	50	47	44	41	39	35
4	250	222	200	192	168	160	148	143	138	133	129	125	121	114	111	100	89	80	73	67	62	57	53	50	47	44	40
4.5	281	250	225	216	189	180	167	161	155	150	145	141	136	129	125	113	100	90	82	75	69	64	60	56	53	50	45
5	313	278	250	240	210	200	185	179	173	167	162	157	152	143	139	125	111	100	91	84	77	72	67	63	59	56	50
5.5	344	305	275	264	231	220	204	196	190	183	178	172	167	157	153	138	122	110	100	92	85	79	73	69	65	61	55
6	375	333	300	288	252	240	222	214	207	200	194	188	182	172	167	150	133	120	109	100	92	86	80	75	71	67	60
6.5	406	361	325	312	273	260	241	232	224	216	210	203	197	186	181	163	144	130	118	109	100	93	86	81	77	72	65
7	438	389	350	336	294	280	259	250	242	233	226	219	212	200	195	175	155	140	127	117	108	100	93	88	83	78	70
7.5	469	416	375	360	315	300	278	268	259	250	242	235	227	215	209	188	167	150	137	125	116	107	100	94	89	83	75
8	500	444	400	384	336	320	296	286	276	266	258	250	242	229	222	200	178	160	146	134	123	114	106	100	94	89	80
8.5	531	472	425	408	357	340	315	303	293	283	275	266	258	243	236	213	189	170	155	142	131	122	113	106	100	94	85
9	563	500	450	432	378	360	333	321	311	300	291	282	273	257	250	225	200	180	164	150	139	129	120	113	106	100	90
9.5	594	527	475	456	399	380	352	339	328	316	307	297	288	272	264	238	211	190	173	159	146	136	126	119	112	105	95
10	625	555	500	480	420	400	370	357	345	333	323	313	303	286	278	250	222	200	182	167	154	143	133	125	118	111	100
10.5	656	583	525	504	441	420	389	375	362	350	339	329	318	300	292	263	233	210	191	175	162	150	140	131	124	117	105
11	688	611	550	528	462	440	407	393	380	366	355	344	333	315	306	275	244	220	200	184	169	157	146	138	130	122	110
11.5	719	638	575	552	483	460	426	411	397	383	371	360	348	329	320	288	255	230	209	192	177	164	153	144	136	128	115
12	750	666	600	576	504	480	444	428	414	400	388	376	364	343	334	300	266	240	218	200	185	172	160	150	142	133	120
12.5	781	694	625	600	525	500	463	446	431	416	404	391	379	358	348	313	278	250	228	209	193	179	166	156	148	139	125
13	813	722	650	624	546	520	481	464	449	433	420	407	394	372	361	325	289	260	237	217	200	186	173	163	153	144	130
14	875	777	700	672	588	560	518	500	483	466	452	438	424	400	389	350	311	280	255	234	216	200	186	175	165	155	140
Conversion Factor	62.5	55.5	50	47.6	41.7	40	37.0	35.7	34.5	33.3	32.3	31.3	30.3	28.6	27.8	25	22.2	20	18.2	16.7	15.4	14.3	13.3	12.5	11.8	11.1	10

Formula: L/tree = L/100 m ÷ 100 x tree spacing (m) L/100 m = L/tree x 100 ÷ tree spacing (m)

Note: This table and formula treat the tree row as a continuous hedge (regardless of actual tree width) as most sprayers can not distinguish between canopy and empty space.

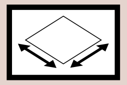
Figure 55

UNITS AND SPRAY VOLUME FACTORS TO DESCRIBE SPRAY VOLUMES

Linear/Square/Cubic units Various units are used in the horticultural industry to describe the appropiate amount of spray solution. They range from one dimensional L/100 m row over two dimensional L/100 m per m height or L/ha to three dimensional L/tree or L/100 m^3. Some measurements are more practical than others but in principle, using the right formulas, they all can be transformed into each other. Differences between these measurements are largely academic and often related to the preferences of a dominant researcher/consultant in a specific crop or geographical area. Automatic rate controllers operate mainly in L/ha in L/100 m. Horticultural industry and research body agreement on a single unit would allow everybody to use the same terminology.

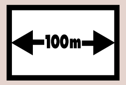
Spray Volume Factor Whatever linear/square/cubic unit is used, the unit still needs to be multiplied with a crop specific Spray Volume Factor. These factors are the result of research and link a water volume with the linear/square/cubic units to describe a spray volume, e.g. 6 L per 100 m^3 (macadamias), or 20 L/100 m per m height. Some researchers link Spray Volume Factors strictly to canopy volume, others are confident that height only is sufficient, bearing enough correlation to all other aspects.

More recent approaches use a height and a density factor only and express the volume in L/100 m row. Latter is the method preferred in this publication. It is simple and astonishingly unifying (Figure 51).

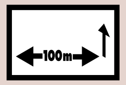


L/HA L/ha is the commonly used rate expression in broadacre situations. Many argue that such a two-dimensional area measurement can't account for the three dimensional character of horticultural crops. However in most situations, formulas and experience are applied to take into consideration the differences between various canopies and row spacings. After decades of use in most crops the L/ha unit is still the most understood unit to describe the water volume needed. For the moment the L/ha rate is here to stay, even as a valuable cross reference only. The industry is not so familiar with alternative measurements yet so it is very handy to check back to a more familiar L/ha rate. To most growers 40 L/100 m row may seem abstract, whereas the equivalent unit of 1200 L/ha (for 3.3 m row spacing) helps them to relate easily to past and current standards.

Most all chemical rate related financial and management decisions are still based on per ha calculations. All automatic rate controllers have a L/ha mode.

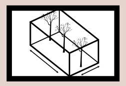


L/100 M ROW Also known as Distance Based Calibration L/1000m increasingly used in crops with little height variation, e.g. grapes. This unit has several advantages over other units. It is simple. It contains only 2 measurements – volume and distance, e.g. 20 L/100 m row. Row spacing is irrelevant. That makes it easy to calibrate. as formulas are not required. The grower only needs to mix up the concentration per 100 L as stated on the label. Three-dimensional factors (always height, often width and sometimes density) are already considered in the recommended Spray Volume look-up tables. Many automatic rate controllers have a per L/100 m option.



L/100 M PER M HEIGHT L/100m per m height is by far the easiest and most practical unit to use. It works on the same principle as the L/100 m row approach, but also takes into consideration that tree heights vary. Taller trees need a higher volume for coverage. In essence, a L/100 m volume needs to be multiplied by the height of the tree. L/100m per m height can easily be transferred into L/100 m and its simplicity is appealing. As a general rule of thumb most vertical crops can be sprayed with dilute rates of 20–30 L/100 m per m height (Figure 51).

VOLUMETRIC CANOPY BASED UNITS



Tree Row Volume In its simplest form, the grower calculates the tree canopy volume by multiplying height (skirt to top) x width (across the row) x 100 m row and multiplies the volume with a Spray Volume Factor. For some crops, such as apples, the applied Spray Volume Factor takes different tree shapes and leaf densities into consideration.

A SPRAYER TRAVELLING ALONG A ROW, NEEDS TO COVER SPACE, REGARDLESS IF THERE IS A CANOPY OR NOT.

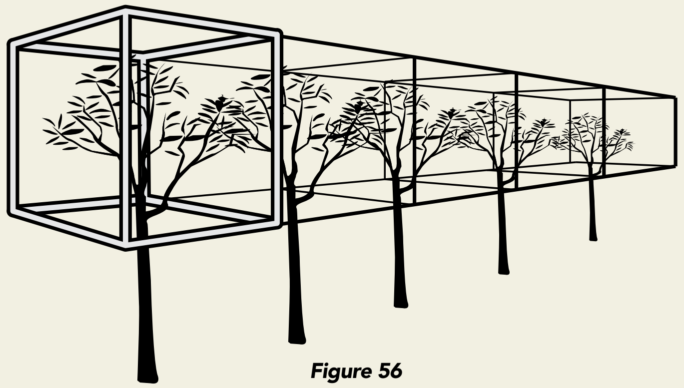
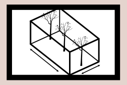


Figure 56



L/100 M^3 OR M^3/L An accurate way to account for canopy size, this unit still has to take inter-row space into consideration to translate the unit into L/ha or L/100 m row to calibrate. This unit appears more relevant for research but less user friendly for the grower.

Some researchers argue that for small trees the width of the tree along the row should be measured, rather than the tree spacing. However in practice a sprayer does not differentiate and cannot shut down in between trees (unless equipped with sensors).

L/TREE This unit is popular in tropical regions of Australia. However, alone it does not help calibration and still needs to be transformed into a different unit. Normally it is derived by matching the average canopy size with a crop specific Spray Volume Factor, e.g. 6 L/100 m^3 in mangoes. For trees with 33 m^3 that implies a volume of 2 L/tree. Again, note that the tree spacing along the row should be applied for the calculation, not the width of the tree (see above). L/tree units need transformation into calibration friendly units usually done by multiplying the factor with the number of trees/ha, resulting in a L/ha figure.

CANOPY DENSITY, LEAF INDEX AREA

Canopy density is an important factor to establish an appropriate spray volume. Measurements include leaf index area where the number and size of leaves in a given volume are added up to quantify the density of a tree. Many Spray Volume Factors take this dimension into consideration and distinguish between sparse, medium and dense foliage.

CHAPTER SUMMARY

- Low volume spraying - also called Concentrate Spraying - is undertaken when the applicator uses a spray volume that is below the Dilute Volume.
- An X Factor is often used to indicate the ratio that exists between the Concentrate Volume and the Dilute Volume, e.g. 2X when 500 L/ha is used instead of 1000 L/ha Dilute Volume or 10 L/100 m instead of 20 L /100 m
- The pesticide dilute label rate needs to be multiplied with the X Factor, e.g. 140 g /100 L becomes 280 g/100 L at 2X
- It is importantto ensure that the equipment is designed and set up for concentrate spraying to achieve even coverage
- Improved airflow and adjuvant technology make Concentrate Spraying a reliable, robust way to substantially save on input costs and have operational flexibility.
- Care needs to be taken when using Plant Growth Regulations (PGRs) in Concentrate Spraying. Initial small plot testing is advisable

LOW VOLUME (CONCENTRATE) SPRAYING

Low volume spraying, also called Concentrate Spraying, is undertaken when the applicator uses a spray volume that is below the Dilute Volume. The term 'concentrate' refers to the fact that the concentration of chemical per 100 L is increasing in direct proportion to the reduction in spray volume.

For example, if the Dilute Volume required is 1000 L/ha and the actual application volume is only 500 L/ha double the label rate per 100 L is needed to apply the same dose. For example, instead of the dilute label rate of 140 g Nufarm Champ®/100 L the applicator would need to mix up 280 g Nufarm Champ®/100L. As a result they will apply the same dose to the canopy (5 x 280 = 1.4 kg/ha equals 10 x 140 g = 1.4 kg/ha) (Figure 49, page 24).

X Factor An X Factor is often used to indicate the ratio that exists between the Concentrate Volume and the Dilute Volume. In the example above the application would be described as '2X'. A Concentrate Volume of 250 L/ha, compared with a 1000 L/ha Dilute Volume it would be defined as a '4X' application. The X Factor indicates automatically the multiplication factor for the dilute label rate. In the Nufarm Champ® example the multiplication factor for 250 L/ha or 4X would be four (4 x 140 = 560g/100L). This would still be equivalent to 1.4 kg/ha (2.5 x 560 = 1.4 kg/ha).

Check that the equipment is designed and set up for concentrate spraying. This is usually achieved by using nozzles producing mainly a FINE spray quality and by using equipment producing a sophisticated airflow.

BENEFITS OF CONCENTRATE SPRAYING

Spraying with high water volumes generally means higher application costs, lower work rates, and reduced operational flexibility. Reducing the water rate can provide substantial savings for the grower (Figure 57). One tank fill lasts longer, saving valuable time re-filling. Larger operations may only need to operate two sprayers instead of three. Benefits will vary between enterprises depending on parameters applied.

Experience shows that a concentrate spray around 3X usually results in a 10–15% higher deposition rate of chemical.

WHY THEN IS CONCENTRATE SPRAYING NOT USED MORE OFTEN AS THE STANDARD METHOD?

Lower spray volumes mean generally lower levels of coverage. The lower the water volume, the lower the margin for error. In the past, growers have used equipment and set-ups not designed to apply low water volumes. They did not achieve sufficient, even coverage, lost efficacy and went back to Dilute Volume spraying. Nowadays with improved airflow and adjuvant technology has overcome these problems and enables growers to apply concentrate sprays with great confidence. In many cases using a concentrate spray will actually result in an increase of coverage and deposition.

Saving time allows for better timing to respond to pest and disease threats.

PESTICIDE RECOMMENDATIONS FOR CONCENTRATE SPRAYING

Many pesticide labels contain concentrate statements. These statements usually reflect that the manufacturer has undertaken trials up to this level of concentration and is not prepared to give recommendations beyond that. Less commonly, the chemical may have caused some crop effect when used in concentrations exceeding the label statement. Chemicals with a high loading of aggressive solvents may cause crop injury when are impact in high concentrations on small leaf areas.

Plant Growth Regulators (PGRs) are usually used with high water rates, often as flood application beyond the Dilute Volume. Growers accept high levels of loss on the outer canopy to optimize coverage on the target, e.g. Gibberellic Acid (GA) application in Citrus. Great care needs to be taken when altering water volumes with PGRs in dense canopies.

A Concentrate Spray is likely to increase the deposition many-fold on the outer canopy. Higher pesticide levels on the plant are usually not detrimental with fungicides and insecticides but could be catastrophic with some PGRs. Small plot testing is advisable.

TYPICAL LABEL STATEMENTS

DO NOT use concentrations exceeding 4X
DO NOT use at concentrate rates greater than 250 g/100 L
Use a minimum spray volume of 250 L/ha

COST COMPARISON BETWEEN DILUTE/FLOOD SPRAY PROGRAM AND CONCENTRATE SPRAY PROGRAM, EXAMPLE CITRUS

Cost comparison airblast/ Croplands Quantum Mist™ Example from Mildura Citrus Grower	Airblast	Croplands Quantum Mist™	
	Conventional water volume	Reduced water volume	Low water volume plus Du-Wett
Adjuvant costs			
Normal adjuvant rate (for example Agral or Viti-Wet)	15 mL/100 L	15 mL/100 L	
Costs in $/L	$9.50	$9.50	
Super spreader Du-Wett/Designer rate mL/ha			350 mL/ha
Costs in $/L			$55.00
Adjuvant costs/ha	$7.13	$4.99	$19.25
Application details			
High water volume application rate (eg mealybugs)	7000 L	5000 L	1200 L
Low water volume application rate (e.g. trace elements)	3000 L	2000 L	1000 L
Number of applications per year	10	10	10
Travel speed high volume	2 km/h	4 km/h	4 km/h
Travel speed low volume	6 km/h	6 km/h	6 km/h
Minutes needed to spray 1 ha - Average	21 min	16 min	16 min
Tank capacity in L	3000 L	4000 L	4000 L
Ha sprayed per tank volume - Average	0.6	1.1	3.6
Average time for refill of tank in min	30	30	30
Minutes needed to spray 1 ha, incl. Refill - Average	71	43	25
Working hours/day	8	8	8
Ha sprayed/day	6.8	11.2	19.2
Ha sprayed hour	0.8	1.4	2.4
Size of orchard/farm in ha	80	80	80
Days required to spray whole orchard	11.8	7.1	4.2
Labour/machinery costs			
Labour cost in $/hour	$30.00	$30.00	$30.00
Machinery cost in $/hour	$60.00	$60.00	$60.00
Labour/machinery cost/ha	**$112.50**	**$64.03**	**$37.50**
Total application costs			
Total costs/ha (labour/machinery/adjuvants)	$119.63	$69.02	$56.75
Total costs whole orchard per application	$9,570	$5,522	$4,540
Total costs whole orchard per year	**$95,700**	**$55,216**	**$45,400**

Figure 57 Application costs (including adjuvants) only. Costs do NOT include costs for pesticides. Additional Watersavings of 4.2 megalitres/year.

COVERAGE

CHAPTER SUMMARY

- Coverage of the target must be even to ensure proper dose distribution
- Different chemistries varying abilities to move within a plant so coverage dependency varies
- Adjuvants are essential to optimise coverage on difficult to wet surfacesGood machinery set-ups are essential to cover inner canopies in dense crops
- Water volumes above dilute should be the last resort to increase coverage
- FINE droplets will result in better deposition
- COARSE droplets will carry further and are an option for more distanced targets

FUNGICIDE PERFORMANCE - SYSTEMIC EFFECTS

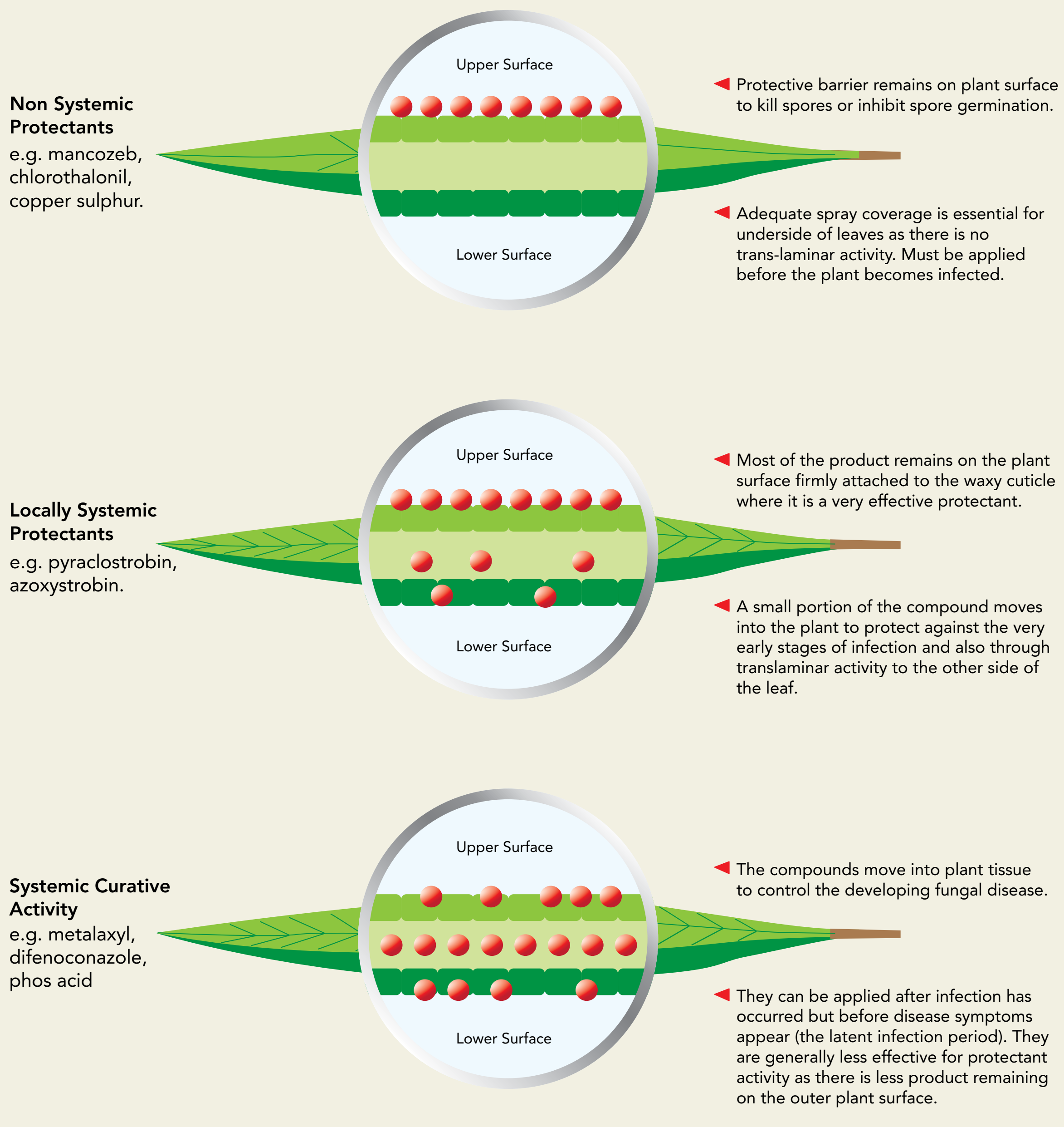


Figure 58

COVERAGE

REPELLENCY

Figure 59

UNEVEN COVERAGE ON BERRIES COMPARED TO LEAVES, 800L/HA

Figure 60

The previous two chapters dealt with the concept of getting the right amount of chemical dosage onto the target. Another critical part of the application process is to distribute the dose as even as possible and to maximise coverage.

CHEMISTRY AND COVERAGE

Many chemicals used in agriculture show only limited movement in or on the plant. For surface active fungicides such as Nufarm Champ®, coverage is critical because the active does not move – it settles where the droplet dries. Usually, these chemicals have only limited redistribution properties (Figure 58).

Many other fungicides such as DeMethlation Inhibitors (DMIs) move only in the xylem (water transport bundles) so can only travel in one direction – upwards, towards the tip of the leaf (acropetal movement). Any uncovered plant area below the lowest deposition point has little protection.

For fungicides without translaminar capability (movement from one side of the leaf to the other) coverage of the upper as well as the lower side of the leaf is critical.

Very few fungicides, for example phosacid, are truly systemic and fully mobile in the plant. They can move in the xylem and in the phloem (nutrients carrying transport bundles).
Effective control of cryptic pests with limited movement, such as mealybugs, aphids or scale insects, relies on optimised coverage because the majority of insecticides is only surface active.

SURFACE AND COVERAGE

Many plant and fruit surfaces are extremely repellent (Figure 59). To deposit a droplet on the lower side of an avocado leaf or on the waxy, erect leaf of an onion or brassica crop is a challenge. Generally, smaller droplets show better deposition properties on hard to wet surfaces than larger droplets.

Even within the same crop, surfaces can vary significantly. While it is easy to deposit a droplet on a vine leaf, it is difficult to do the same on a waxy berry bunch (Figure 60).

In most cases, the use of an adjuvants is essential to optimise droplet deposition and increase coverage on difficult to wet surfaces.

CANOPY AND COVERAGE

In tree and vine crops and dense vegetable crops, the density of foliage can be a major hurdle to achieving satisfactory, even coverage in the inner canopy. The use of air-assist equipment is essential. However, even with air assist, to cover in inner canopies less than half the area covered in the outer canopies. The denser the canopy, the more important the type of air assist (see page 16).

In many situations, when the crop is still young and easy to cover, it is fundamentally important to keep the foliage free of disease for as long as possible because it will become increasingly difficult to achieve good coverage later on.

To open up the canopy with air assist equipment takes time, so speed can a limit factor good coverage.

A properly tested machinery set-up is critical in tackling dense canopies. The direction and velocity of the airstream needs adjusting and the right nozzle/adjuvant/volume combination selected.

If coverage in the inner canopy is poor, it is wise to take a robust chemical approach. Products that can move (acropetal and translaminar) will be better than purely surface active products. Robust product rates will be needed. Adjuvants can help significantly.

COVERAGE

WATER VOLUME AND COVERAGE

Traditionally it has been thought that high water volumes, using dilute or flood volumes, will improve coverage. High volumes can help to a degree to overcome poor sprayer set-up or inefficient equipment, but in many cases will do little to improve efficacy significantly. In dense canopies the type of air assist is more important than water volume. Once the leaves of the outer canopy start to tile against each other, they create a barrier that will not be overcome by higher water volumes – it will simply create more run-off with only a marginal increase of penetration into the inner canopy. Volumes of at least twice the Dilute Rate need to be used (e.g. 7000-10000 L/ha in the Citrus industry) if water volume is the sole method being used to increase coverage in dense canopies. High water rates have proven to increase efficacy on mites and cryptic pests. However, this approach leads to higher application costs through low work rates, high chemical usage rates, waste of water and loss of flexibility. Plus, going through this time consuming process will not guarantee higher deposition rates.

Increasing the water volume will do little to improve retention on difficult to wet surfaces. The young cabbage (Figure 61) was sprayed with 330 L/ha containing the white clay marker AgNova Surround® (see page 42). The wild potato in the top corner of the image and the grass blades growing across the cabbage are well covered. But there is nothing on the cabbage. The volume simply ran off the repellent surface. Conventional wisdom may suggest only a higher water volume but this will create more run-off. The solution to overcome the waxy plant surface is to reduce water volume to a level where it is less likely to run off and to manipulate the droplet to achieve deposition and coverage by using adjuvant technology, in this case Nufarm Du-Wett® (see page 38).

Nufarm Du-Wett® spreads the 'little' water there is to create an even film. The same principle applies for all hard-to-wet surfaces (e.g. brassicas, onions, avocados, grape bunches).

High volumes of spray solution on the plant surface have the tendency to pool together - and once dried out - create concentrated cakes of chemicals (Figure 60). This results in uneven coverage and increased risk for crop effect because a high concentration of chemical sitting on a small area. It can also result in slow breakdown of chemistry (i.e. residues). In contrast, using a concentrate spray with the addition of Nufarm Du-Wett® will result in an even coverage with reduced potential for caking.

When it comes to choosing a water rate for the optimum sprayer set-up, in most instances less is more. Concentrate spraying with the addition of Nufarm Du-Wett® will achieve better or at least equal coverage compared with Dilute Spraying, but it will provide all the benefits of improved work rate.

NOZZLES AND COVERAGE

Nozzles producing FINE droplets will generally work better with air-assist than nozzles that produce a COARSE spray quality. Smaller droplets have less momentum and are directed easier by the air flow. They tend to swirl better and deposit easier on difficult to wet surfaces. The majority of nozzles in horticulture are therefore hollow cone nozzles, producing a VERY FINE to FINE spray quality. On the other hand, coarser droplets, because they have more momentum, will travel further and reach more distant targets better than FINE droplets, e.g. tops of high canopy trees.

If the target area is more than 4m away from the nozzle, the use of air induction nozzles or solid cone nozzles, producing a COARSE spray quality is warranted. A sprayer may require a few air-induction nozzles on the top to reach the tree tip with hollow cone nozzles covering the rest of the canopy. Directing coarser droplets to the tip will reduce drift potential. Very high trees may require a canon nozzle to get some volume up to the top.

When mixing nozzle types ensure that all nozzles are working within their optimum pressure range.

In vegetable crops the use of angled flat fan nozzles can increase coverage.

COVERAGE

FARMER APPLICATION OF NUFARM DU-WETT®

Farmer application. Note coverage on grass across the cabbage and potato next to it. Excellent coverage achieved by routine spray with 330 L/ha. However not much left on the target itself. Increasing water volume on hard to wet surfaces does not mean increasing coverage.

In comparison, total coverage with Nufarm Du-Wett® at 150 L/ha (wet dark bits still need to dry).

Figure 61 *Demo with Ace Ohlsen in Windsor, NSW, March 2005. Clay marker AgNova Surround® was used at 12 kg/ha*

CHAPTER SUMMARY

- Nufarm Du-Wett® spreads up to eight times more than conventional non-ionic surfactants
- Nufarm Du-Wett® negates the coverage disadvantage of concentrate spraying
- Conventional organosilicones are not suitable for safe application in horticulture
- Nufarm Du-Wett® is especially formulated to be safe for horticultural use
- Spray solution can spread into concealed places
- Despite being lower in volume, the spray solution will finish up more evenly distributed
- Substitute Nufarm Du-Wett® with Nufarm Designer® if rain fastness for surface active products is needed

Adjuvants are covered in detail in Chapter 14, see page 67. While most adjuvants will help to increase coverage dedicating a chapter to the unique superspreader Nufarm Du-Wett® is warranted. Nufarm Du-Wett® has the potential to revolutionise the way chemicals are applied in horticulture. It offers greatly increased coverage while enabling growers to use much lower water volumes. Given these potential advantages it is not surprising that the use of such organosilicone superspreaders is not a new concept in horticulture. However the concept never took off in the pastbecause of frequently occurring crop phyto toxicity.

CROP SAFETY

Conventional organosilicones, like Nufarm Pulse®, break water surface tension to levels that allow the spray solution to flood into minute openings, for example, the stomata of leaves. They act effectively as penetrants which is desirable for herbicide applications but not suitable for supplying plant protection products. The physical uptake of spray solution (and chemicals) cannot be controlled. Crop effects, such as burn, can be more obvious or they can be more subtle, such as a reduction in fruit formation (Figure 62).

HOW NUFARM DU-WETT® WORKS

The development of Nufarm Nufarm Du-Wett® has provided new opportunities for growers to use organosilicone technology to their advantage. Nufarm Nufarm Du-Wett® is specifically designed for the safe application of crop protection products in horticulture when using concentrate water volumes (usually 3X). The level of decrease in surface tension is not sufficient to allow major uptake through minute openings. Yet, the product increases the spread area of droplets on the plant leaf surface up to eight times the area covered by conventional non-ionic surfactants. The distribution is more even, like a film (Figure 63), so large spray volumes are not required. Once enhanced with Nufarm Du-Wett®, a single droplet will cover the same area that previously needed many droplets (Figure 64). Nufarm Du-Wett® is the perfect tool to greatly improve coverage in low volume applications.

DU-WETT - CROP SAFETY ON ZUCCHINI

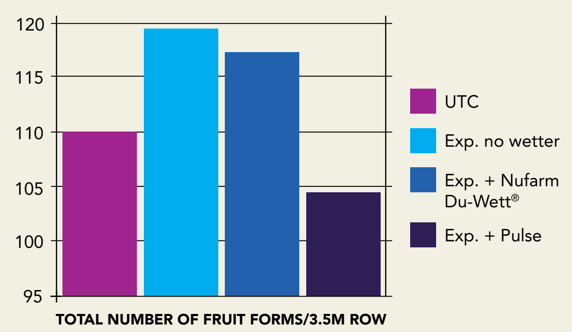


Figure 62 *Source: Phytech, Kununurra, WA 2005 used with an experimental fungicide, measured 6DAA3*

The obvious disadvantage in Concentrate Spraying is less volume to cover the target. Nufarm Du-Wett® negates this problem by spreading the little volume there is more evenly than a Dilute Volume would do.

Many target surfaces are waxy and repel spray solution. On those surfaces Dilute Volumes tend to run off or pool (Figures 60 & 61) , finishing up in concentrated and caked chemicals. A concentrated spray solution enhanced with Nufarm Du-Wett® avoids excessive run-off and optimises coverage (Figure 65).

EVEN COVERAGE ACHIEVED WITH NUFARM DU-WETT® AT 250 L/HA (6X)

Figure 63

SPREAD OF DROPLET ENHANCED WITH NUFARM DU-WETT®, AVOCADO LEAF

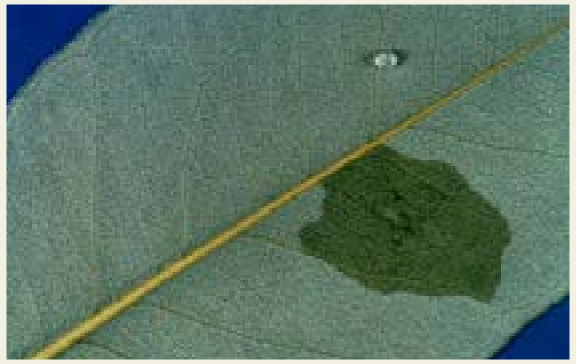


Figure 64

The spray solution is also able to spread into spaces not accessible to conventional spray solutions (e.g. tight grape bunches for control of botrytis, or sooty mould areas surrounding mealybugs). Nufarm Du-Wett® is also an excellent deposition agent, improving the deposition of droplets on difficult targets like onions.

INTERACTION WITH CHEMICALS

Concerns have been raised by horticulturists that Nufarm Du-Wett® does not allow sufficient drying time for products to be taken up into the plant. Indeed, Nufarm Du-Wett® enhanced spray solutions spread out very thinly and appear to dry very quickly. However, the human eye can't detect rest moisture on the leaf. It takes much longer for the leaf to fully dry than appears to the naked eye in the field.

Furthermore, most chemicals used for horticultural plant protection are fairly insoluble. To stay in suspension they rely on their inert surfactant/solvent system.

These products are commonly brought to market as EC or SC formulations (see the sections on formulations, page 79). The active does not need large amounts of water to stop it from crystallising. Water is used more as the delivery system. Once on the plant surface these products rely on their own and their solvent's affinity to the plant cuticle for uptake. This is very different to highly water soluble actives such as glyphosate.

Drying time is not a major issue with Nufarm Du-Wett® enhanced spray solutions. Surface acting products do not need to be taken up and most fungicides and insecticides that are taken up into the plant do not rely on large amounts of water. This is demonstrated in our overwhelming majority of efficacy data from the field. (For examples, see Figures 68-72).

RESIDUES

In general, deposition of active with Concentrate Sprays using Nufarm Du-Wett® shows a 15–25% increase compared with Dilute. This is due to less run-off and better deposition characteristics of droplets on difficult surfaces. Increased deposition raises questions about residue levels. Studies clearly indicate that chemical residues are actually reduced when using Nufarm Du-Wett® (Figure 67). Comparing Figure 60 with Figure 65 explains why. The Dilute Spray results in heavy concentration and caking of chemical in some areas of the fruit.

Breakdown of chemical in these cakes will be slower and is likely to contribute to most of the residues. In contrast, the Nufarm Du-Wett® enhanced spray solution has spread out evenly allowing an even breakdown of chemical. Residues will be less. The same argument applies to increased crop safety. Even though the Nufarm Du-Wett® spray solution is concentrated, it will be more evenly distributed, decreasing the potential for burn.

COVERAGE WITH NUFARM DU-WETT® & DESIGNER®

EVEN COVERAGE - CONCENTRATE SPRAY WITH NUFARM DU-WETT® AT 3X. A WHITE CLAY MARKER IS USED FOR VISUAL EFFECTS

Figure 65

COPPER RETAINED ON PEPPER LEAVES AFTER 120 MM RAINFALL

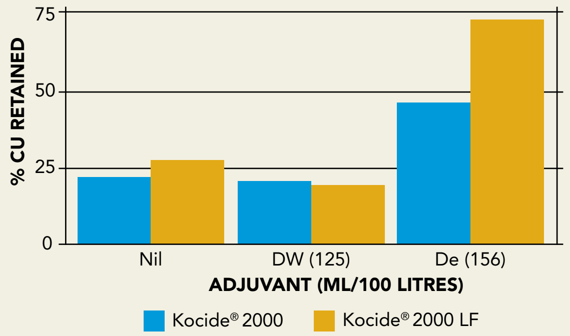


Figure 66 *Source: Elliott Chemicals, NZ*

NUFARM DESIGNER®

While Nufarm Du-Wett® is an excellent product to be used in standard Concentrate Spray programs, it does little to improve rainfastness of surface acting chemicals (Figure 66). It should be substituted with the super spreading sticker Nufarm Designer® when heavy rain is forecast or overhead irrigation is imminent. The latex component of Nufarm Designer® will provide extra protection.

NUFARM DU-WETT®

Nufarm Du-Wett® negates the disadvantages of low water volumes and allows more even coverage than a Dilute Volume would ever achieve. Growers can take all the advantages of lower spray volumes (increased operational flexibility, reduced application costs, better spray timing etc.) without compromising coverage. To make it work, it is essential to use Concentrate Volumes because the plant surface will not be able to hold Dilute Volumes once Nufarm Du-Wett® is mixed in.

RESIDUES

Product	Grams of active/ha per season	Time measured days after treatment (DAT)	Residues in mg/kg fruit: Standard block	Residues in mg/kg fruit: Nufarm Du-Wett® block
Captan	1280 (ST) 1600 (Du)	25 DAT	0.56	0.32
		32 DAT	0.26	0.1
Dodine	640	14 DAT	0.36	0.24
		21 DAT	0.21	0.16
Tebufenozide	180	14 DAT	0.2	0.19
		21 DAT	0.15	0.12

Figure 67

COVERAGE WITH NUFARM DU-WETT® & DESIGNER®

COLLIS AND NUFARM DU-WETT®, WA KUNUNURRA, 2006: ZUCCHINI (CV. CONGO).

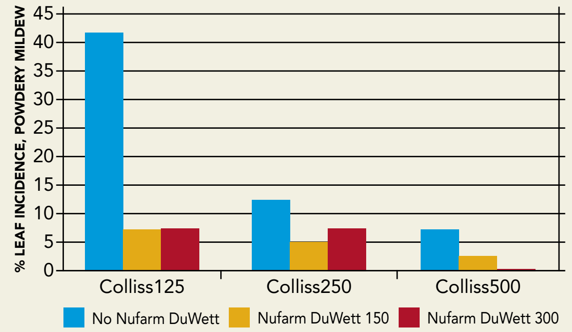


Figure 68 *Source: Phytech*

COLLIS AND NUFARM DU-WETT®, WA KUNUNURRA, 2006: CUCUMBER (CV.CRYSTAL APPLE).

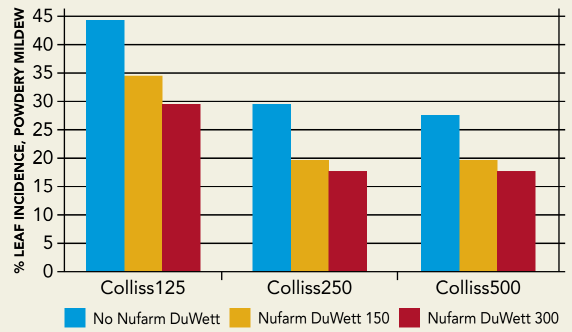


Figure 69 *Source: Phytech*

CONTROL OF CABBAGE MOTH IN CABBAGE, VIRGINIA, SA 2006

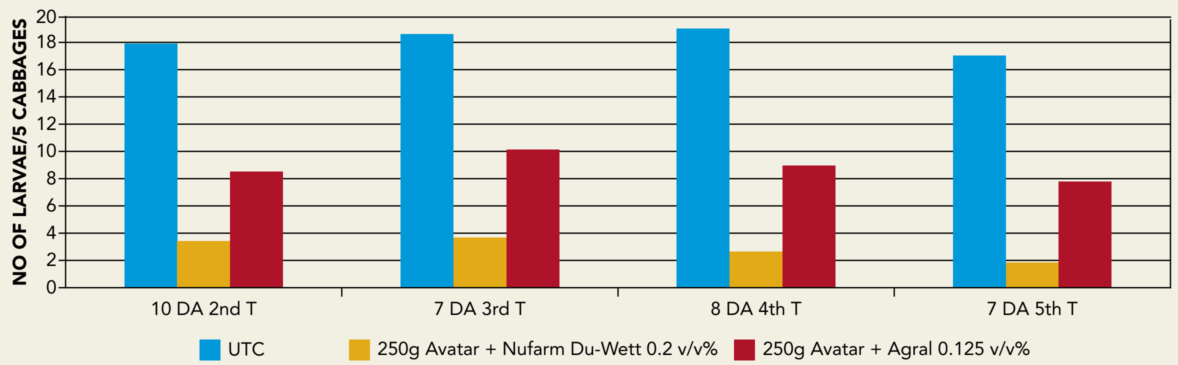


Figure 70 *Source: Agrisearch, water volume 300-450 L/ha*

GRAPES - POWDERY MILDEW CONTROL

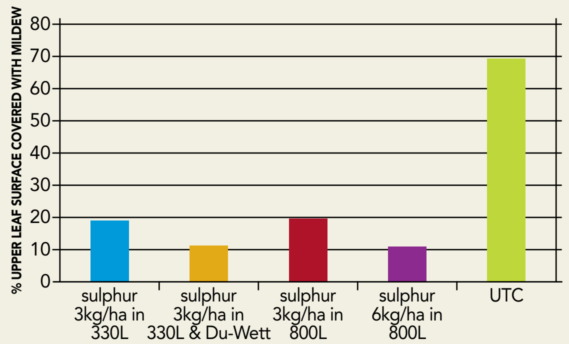


Figure 71 *Source: Trevor Wicks, Riverland*

PEANUTS - EFFICACY AGAINST LEAF SPOT

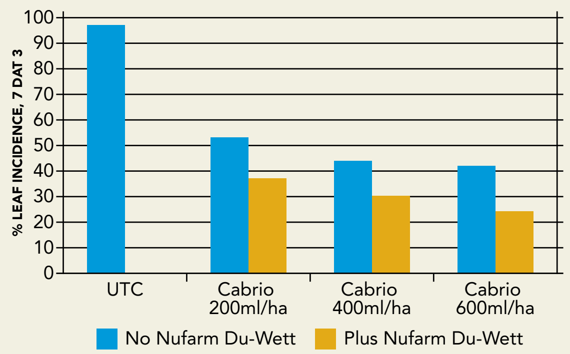


Figure 72 *Source: Agritech, Queensland, Tolga, 2009*

COVERAGE ASSESSMENT

CHAPTER SUMMARY

Check coverage with spray markers:

Clay marker

- Easy to make changes and improve set-ups on the go
- Easy to see over the entire canopy
- Messy to work with

UV dye

- Most visible marker
- Easy to see over large area
- Needs darkness and UV lamps
- Expensive

Water sensitive paper

- Minimal effort
- Easy to document and store results
- Needs standartisation to make proper comparisons
- Only snapshot approach

The sight of a spray cloud interacting with the canopy does not accuratly indicate coverage achieved in the canopy. More often than not the perception of the human eye is not even close to the real coverage achieved. For example, the plumes of high volume applications will generally look reassuringly better than the hardly visible plumes from low volume applications. Yet, coverage with the lower volume is often equivalent or even better. Sprayers that can't penetrate into the canopy will look brilliant to the naked eye because all the volume only wets the outer visible canopy.

Hard to cover surfaces may not allow deposition and what looks superficially like an effective plume may not translate into actual coverage.

Any realistic assessment of spray coverage requires some unbiased standard with the help of spray indicators. Most commonly used are water sensitive papers, clay markers or fluorescent dyes.

Clay markers There are several clay products on the market, mainly for protecting fruits and leaves from sun burn. By far the most visible residues are produced by AgNova Surround® which makes it an excellent product for the assessment of coverage (Figure 73). Spraying with AgNova Surround® shows coverage over the entire canopy as a whole as well as in detail. Uneven banding or shading in the canopy can be picked up very effectively. AgNova Surround® is the best method to demonstrate excessive run-off.

An assessment can be carried out soon after application, once the clay marker has dried. The sprayer can then be modified to correct any shortcomings.

Working with AgNova Surround® is messy. Before application it is wise to cover equipment with some oil spray to make cleaning easier. AgNova Surround® is 95% kaolin, a fine milled clay. No issues with residues will result from this application.

To become visible, the clay droplets need to dry. The intensity of white increases with dryness. It is advisable to wait 20 minutes after application before assessment, even though the clay may be already visible after a few minutes. A good visual spray indicator rate is 1.25 kg/100 L Dilute Volume. For many vegetables and vineyards that relates conveniently to around 1 bag of AgNova Surround® 12.5 kg/ha. For tree crops the rate will work out to around 20 kg/ha. If a Concentrate Spray volume is used the X Factor rules must be applied the brightness of the white will indicate how much (what dose) was delivered onto the target.

Water Sensitive Paper Water sensitive paper is yellow and comes in various sizes but the most common is 76 mm x 26 mm. When a droplet hits the surface the contacted area turns an irreversible blue. Water sensitive paper has the advantage that it is very easy to handle (but watch out for moisture) and store (used and unused) which make it an ideal tool for documentation (Figure 74). It can be assessed straight after the application and like clay, it is excellent for incorporating into the work flow of set-up.

However it provides only a small snapshot of the canopy target, so great care needs to be taken to produce a representative assessment when placing the papers into the canopy. A stick with slots to fit a folded sheet is easily produced (Figure 75).

SPRAY MARKER CLAY

Figure 73

POSSIBLE STANDARD FOR WATER SENSITIVE PAPER

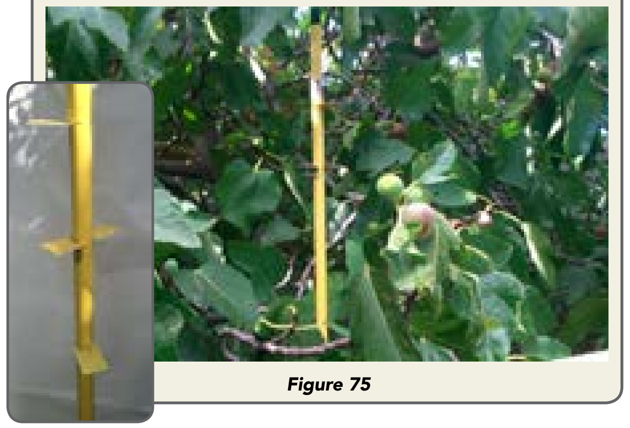


Figure 75

SPRAY MARKER WATER SENSITIVE PAPER

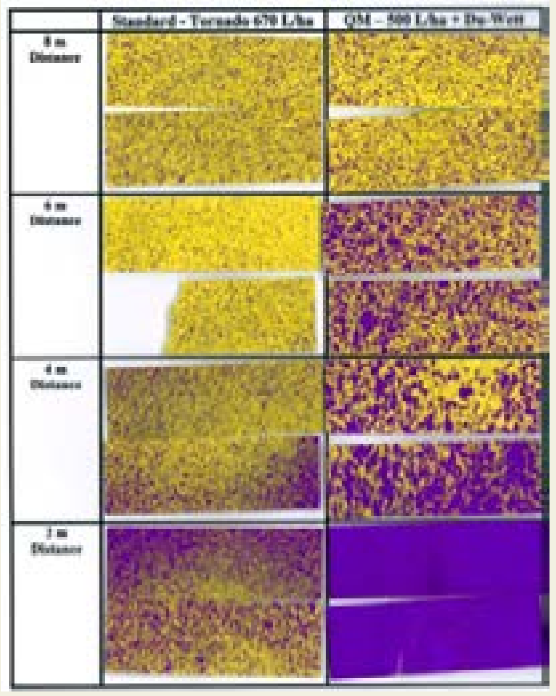


Figure 74

SPRAYMARKER UV - DYE

Figure 76

These sticks can then be placed in the inner and outer canopy and/or lower and higher canopy. This is not perfect, but should be sufficient to create some standardisation between treatments. As a rule of thumb, if 3 out of 10 papers show inadequate coverage, the set-up needs improvement.

Because of the snapshot approach it is difficult to pick up banding or shading effects across the whole canopy during application. Another disadvantage with water sensitive paper is that the surface is absorbing and behaves very differently to plant surfaces. After application the papers should be collected as soon as possible because they tend to absorb humidity.

Fluorescent Dye The glow of fluorescent dye in the light of a fluorescent torch under dark conditions can be quite spectacular (Figure 76). Even the tiniest droplets show up. However, dye is not cheap. The observer also needs a fluorescent torch which can be costly. As a rule of thumb, the smaller the illuminated radius of the torch the less of an overall picture is generated and the more difficult to make an overall assessment of coverage. Assessments are normally carried out of night making it difficult to change set-ups as you go. Alternatively, leaves and fruits can be picked after application and observed in a darkroom during the day.

Torch size is no issue in a dark room. Like water sensitive paper, it is crucial to sample the plant parts in an organised manner to minimise variation. As the rate of dye increases, results become more obvious but also more expensive. Depending on brand, it is recommended to use 500 mL/100 L in dilute spraying. If a concentrate spray volume is used, the X Factor rules must be applied as with clay.

CLAY MARKER VS DYE IN ONIONS

Figure 77

INTERPRETATION OF RESULTS WITH DIFFERENT MARKERS

Applications with dye always seem to produce a superior coverage compared with clay. That is due to the light activated dye is actively glowing in a dark background whereas the clay is purely reflecting light in a daylight background. As a result minute depositions of AgNova Surround® are more difficult to detect. However, clay is less forgiving and it is always easier to see differences between applications with AgNova Surround® compared to with dye.

USING CLAY MARKERS IN MANGOES

Figure 78

CHAPTER SUMMARY

Nozzle Selection is mainly governed by:

- Speed
- Water volume
- Spray quality

Limits may be set by equipment and terrain:

- Heaviness of soil
- Moisture
- Evenness of terrain
- Density of crop

The applicator may be subject to other overriding requirements such as:

- Avoidance of drift
- Maximum efficacy
- Efficiency – higher speed, lower water volumes

Nozzle selection in horticultural boom spray application is mainly governed by speed, water volume and spray quality required. Density of the crop and the terrain (soil and moisture) are often the main limiting factors for speed. The physical capability of the equipment such as maximum pressure may create limitations as well. Requirements may change between applications, depending on the target or chemical used. Often the final selection will be a practical compromise between requirements, convenience and efficacy. Before reading through this chapter it would be of advantage to read the chapter on nozzle types first (see page 7).

POTATOES EXAMPLE

A potato grower wants to apply 300 L/ha and drive at a speed of 8 km/h. Their nozzle spacing is 50 cm. They need to work out nozzle 1) size and 2) type. The size is mainly governed by speed and volume with nozzle type influenced by the desired spray quality.

1. NOZZLE SIZE

There are two ways to work out the required nozzles size. The first is to use an easy and universal formula.

FORMULA APPROACH

L/min/nozzle = L/ha x km/h x W (m) ÷ 600

L/min/nozzle = output per nozzle per minute

L/ha = target volume

Km/h = target speed

W = nozzle spacing or width in metres

600 = constant, needed because units such as minute used in the same calculation as hour (x 60) and km next to ha (x10)

Calculation for the potato example:

L/min/nozzle = 300 L/ha x 8 km/h x 0.5 m ÷ 600

= 2 L/min/nozzle

The potato grower would need nozzles that put out 2 L per minute each.

The table on page 47 shows the output of ISO colour rated flat fan nozzles ranging from the 01 - 08 size. The second column displays the flow rate of nozzle sizes by pressure. The corresponding pressure for each size is expressed in bar in the first column. Go down the column until the output reaches 2 L/min.

Sizes 01, 015, 02 and 025 don't reach that value, they are too small to produce a flow rate of 2 L/min:

- The blue 03 nozzles can produce 2 L/min around 8.5 bar, (Figure 79)
- the red 04 nozzle around 4.6 bar,
- and the brown 05 sized nozzles at 3 bar.

TITLE

	L/HA 50CM NOZZLE SPACING						
	Bar	Flowrate	2 km/h	3 km/h	4 km/h	5 km/h	6 km/h
025	2	0.82	488	328	244	196	164
	3	1	600	400	300	240	200
	4	1.15	692	460	346	276	230
	5	1.29	776	516	388	310	258
	6	1.41	848	564	424	340	282
	7	1.53	916	612	458	366	306
	8	1.63	980	652	490	392	326
	9	1.73	1040	692	520	416	346
	10	1.83	1096	732	548	438	366
03	2	0.98	588	392	294	236	196
	3	1.2	720	480	360	288	240
	4	1.39	832	556	416	332	278
	5	1.55	928	620	464	372	310
	6	1.7	1020	680	510	408	340
	7	1.83	1100	732	550	440	366
	8	1.96	[illegible]	784	588	470	392
	9	2.08	1248	832	624	498	416
	10	[illegible]	1316	876	658	526	438
04	2	1.31	784	524	392	314	262
	3	1.6	960	640	480	384	320
	4	1.85	1108	740	554	444	370
	5	2.07	1240	828	620	496	414
	[illegible]	[illegible]	1356	904	678	544	452
	7	2.44	1468	976	734	586	488
	8	2.61	1568	1044	784	626	522
	9	2.77	1664	1108	832	666	554
	10	2.92	1752	1168	876	702	584
05	[illegible]	[illegible]	980	652	490	392	326
	3	2	1200	800	600	480	400
	4	[illegible]	1384	924	692	554	462
	5	2.58	1548	1032	774	620	516
	6	2.83	1696	1132	848	678	566
	7	3.06	1832	1224	916	734	612
	8	3.26	1960	1304	980	784	652
	9	3.46	2080	1384	1040	832	692
	10	3.65	2192	1460	1096	876	730

Figure 79

SELECTING NOZZLES FOR BOOM APPLICATIONS

EASY LOOK-UP APPROACH

People who don't like formulas can use the table (Figure 81, page 47) to work out the nozzle sizes in an easier way. The top row of the table contains a speed range. The speed in the example is 8 km/h. The 8 km/h column contains pre calculated L/ha for a given nozzle size and pressure. It is as easy as going down the 8 km/h column and finding 300 or the closest number to 300 and to refer to the left side of the same row to find nozzle size and pressure needed (Figure 80). The outcome is the same as in the formula approach, around 2 L/min/nozzle. The obtained output result can be used to look up pressure values in the hollow cone table (Figure 83, page 49).

The pre-calculated values in the table are for 50 cm nozzle spacing only. A conversion factor needs to be used if the spacing varies (Figure 81).

50 CM NOZZLE SPACING

L/HA 50 CM NOZZLE SPACING

	Bar	Flowrate	2 km/h	3 km/h	4 km/h	5 km/h	6 km/h	7 km/h	8 km/h	9 km/h	10 km/h	12 km/h	14 km/h
	2	0.33	192	128	96	77	64	54	48	43	38	32	27
	3	0.4	234	156	117	94	78	66	59	52	47	39	33
	4	0.46	270	180	135	108	90	78	68	60	54	45	39
	5	0.52	300	200	150	120	100	86	75	67	60	50	43
01	6	0.57	330	220	165	132	110	94	83	73	66	55	47
	7	0.61	368	236	184	142	118	102	92	79	71	59	51
	8	0.65	392	256	196	154	128	110	98	85	77	64	55
	9	0.69	416	268	208	160	134	114	104	89	80	67	57
	10	0.73	440	284	220	170	142	122	110	95	85	71	61
	2	0.49	296	196	148	118	98	84	74	65	59	49	42
	3	0.6	360	240	180	144	120	102	90	80	72	60	51
	4	0.69	416	276	208	166	138	118	104	92	83	69	59
	5	0.78	464	312	232	186	156	132	116	104	93	78	66
015	6	0.85	508	340	254	204	170	146	127	113	102	85	73
	7	0.92	552	368	276	220	184	158	138	123	110	92	79
	8	0.98	588	392	294	236	196	168	147	131	118	98	84
	9	1.04	624	416	312	250	208	178	156	139	125	104	89
	10	1.1	656	440	328	262	220	188	164	147	131	110	94
	2	0.65	392	260	196	156	130	112	98	87	78	65	56
	3	0.8	480	320	240	192	160	138	120	107	96	80	69
	4	0.92	556	368	278	222	184	158	139	123	111	92	79
	5	1.03	620	412	310	248	206	178	155	137	124	103	89
02	6	1.13	680	452	340	272	226	194	170	151	136	113	97
	7	1.22	732	488	366	294	244	210	183	163	147	122	105
	8	1.31	784	524	392	314	262	224	196	175	157	131	112
	9	1.39	832	556	416	332	278	238	208	185	166	139	119
	10	1.46	876	584	438	350	292	250	219	195	175	146	125
	2	0.82	488	328	244	196	164	140	122	109	98	82	70
	3	1	600	400	300	240	200	172	150	133	120	100	86
	4	1.15	692	460	346	276	230	198	173	153	138	115	99
	5	1.29	776	516	388	310	258	222	194	172	155	129	111
025	6	1.41	848	564	424	340	282	242	212	188	170	141	121
	7	1.53	916	612	458	366	306	262	229	204	183	153	131
	8	1.63	980	652	490	392	326	280	245	217	196	163	140
	9	1.73	1040	692	520	416	346	296	260	231	208	173	148
	10	1.83	1096	732	548	438	366	314	274	244	219	183	157
	2	0.98	588	392	294	236	196	168	147	131	118	98	84
	3	1.2	720	480	360	288	240	206	180	160	144	120	103
	4	1.39	832	556	416	332	278	238	208	185	166	139	119
	5	1.55	928	620	464	372	310	266	232	207	186	155	133
03	6	1.7	1020	680	510	408	340	290	255	227	204	170	145
	7	1.83	1100	732	550	440	366	314	275	244	220	183	157
	8	1.96	1176	784	588	470	392	336	294	261	235	196	168
	9	2.08	1248	832	624	498	416	356	312	277	249	208	178
	10	2.19	1316	876	658	526	438	376	329	292	263	219	188
	2	1.31	784	524	392	314	262	224	196	175	157	131	112
	3	1.6	960	640	480	384	320	274	240	213	192	160	137
	4	1.85	1108	740	554	444	370	316	277	247	222	185	158
	5	2.07	1240	828	620	496	414	354	310	276	248	207	177
04	6	2.26	1356	904	678	544	452	388	339	301	272	226	194
	7	2.44	1468	976	734	586	488	418	367	325	293	244	209
	8	2.61	1568	1044	784	626	522	448	392	348	313	261	224
	9	2.77	1664	1108	832	666	554	476	416	369	333	277	238
	10	2.92	1752	1168	876	702	584	500	438	389	351	292	250
	2	1.63	980	652	490	392	326	280	245	217	196	163	140
	3	2	1200	800	600	480	400	342	300	267	240	200	171
	4	2.31	1384	924	692	554	462	396	346	308	277	231	198
	5	2.58	1548	1032	774	620	516	442	387	344	310	258	221
05	6	2.83	1696	1132	848	678	566	484	424	377	339	283	242
	7	3.06	1832	1224	916	734	612	524	458	408	367	306	262
	8	3.26	1960	1304	980	784	652	560	490	435	392	326	280
	9	3.46	2080	1384	1040	832	692	594	520	461	416	346	297
	10	3.65	2192	1460	1096	876	730	626	548	487	438	365	313
	2	1.96	1568	784	784	470	392	336	392	261	235	196	168
	3	2.4	1920	960	960	576	480	412	480	320	288	240	206
	4	2.77	2216	1108	1108	666	554	476	554	369	333	277	238
	5	3.1	2480	1240	1240	744	620	532	620	413	372	310	266
06	6	3.39	2716	1356	1358	814	678	582	679	452	407	339	291
	7	3.67	2932	1468	1466	880	734	628	733	489	440	367	314
	8	3.92	3136	1568	1568	940	784	672	784	523	470	392	336
	9	4.16	3324	1664	1662	998	832	712	831	555	499	416	356
	10	4.38	3504	1752	1752	1052	876	752	876	584	526	438	376
	2	2.61	1568	1044	784	628	522	448	392	348	314	261	224
	3	3.2	1920	1280	960	768	640	548	480	427	384	320	274
	4	3.7	2216	1480	1108	886	740	634	554	493	443	370	317
	5	4.13	2480	1652	1240	992	826	708	620	551	496	413	354
08	6	4.53	2716	1812	1358	1086	906	776	679	604	543	453	388
	7	4.89	2932	1956	1466	1174	978	838	733	652	587	489	419
	8	5.22	3136	2088	1568	1254	1044	896	784	696	627	522	448
	9	5.54	3324	2216	1662	1330	1108	950	831	739	665	554	475
	10	5.84	3504	2336	1752	1402	1168	1002	876	779	701	584	501

Figure 80

SELECTING NOZZLES FOR BOOM APPLICATIONS

BROADCAST APPLICATIONS WITH FLAT FAN NOZZLES

L/HA 50CM NOZZLE SPACING

	Bar	Flowrate	2 km/h	3 km/h	4 km/h	5 km/h	6 km/h	7 km/h	8 km/h	9 km/h	10 km/h	12 km/h	14 km/h
	2	0.33	192	128	96	77	64	54	48	43	38	32	27
	3	0.4	234	156	117	94	78	66	59	52	47	39	33
	4	0.46	270	180	135	108	90	78	68	60	54	45	39
	5	0.52	300	200	150	120	100	86	75	67	60	50	43
01	6	0.57	330	220	165	132	110	94	83	73	66	55	47
	7	0.61	368	236	184	142	118	102	92	79	71	59	51
	8	0.65	392	256	196	154	128	110	98	85	77	64	55
	9	0.69	416	268	208	160	134	114	104	89	80	67	57
	10	0.73	440	284	220	170	142	122	110	95	85	71	61
	2	0.49	296	196	148	118	98	84	74	65	59	49	42
	3	0.6	360	240	180	144	120	102	90	80	72	60	51
	4	0.69	416	276	208	166	138	118	104	92	83	69	59
	5	0.78	464	312	232	186	156	132	116	104	93	78	66
015	6	0.85	508	340	254	204	170	146	127	113	102	85	73
	7	0.92	552	368	276	220	184	158	138	123	110	92	79
	8	0.98	588	392	294	236	196	168	147	131	118	98	84
	9	1.04	624	416	312	250	208	178	156	139	125	104	89
	10	1.1	656	440	328	262	220	188	164	147	131	110	94
	2	0.65	392	260	196	156	130	112	98	87	78	65	56
	3	0.8	480	320	240	192	160	138	120	107	96	80	69
	4	0.92	556	368	278	222	184	158	139	123	111	92	79
	5	1.03	620	412	310	248	206	178	155	137	124	103	89
02	6	1.13	680	452	340	272	226	194	170	151	136	113	97
	7	1.22	732	488	366	294	244	210	183	163	147	122	105
	8	1.31	784	524	392	314	262	224	196	175	157	131	112
	9	1.39	832	556	416	332	278	238	208	185	166	139	119
	10	1.46	876	584	438	350	292	250	219	195	175	146	125
	2	0.82	488	328	244	196	164	140	122	109	98	82	70
	3	1	600	400	300	240	200	172	150	133	120	100	86
	4	1.15	692	460	346	276	230	198	173	153	138	115	99
	5	1.29	776	516	388	310	258	222	194	172	155	129	111
025	6	1.41	848	564	424	340	282	242	212	188	170	141	121
	7	1.53	916	612	458	366	306	262	229	204	183	153	131
	8	1.63	980	652	490	392	326	280	245	217	196	163	140
	9	1.73	1040	692	520	416	346	296	260	231	208	173	148
	10	1.83	1096	732	548	438	366	314	274	244	219	183	157
	2	0.98	588	392	294	236	196	168	147	131	118	98	84
	3	1.2	720	480	360	288	240	206	180	160	144	120	103
	4	1.39	832	556	416	332	278	238	208	185	166	139	119
	5	1.55	928	620	464	372	310	266	232	207	186	155	133
03	6	1.7	1020	680	510	408	340	290	255	227	204	170	145
	7	1.83	1100	732	550	440	366	314	275	244	220	183	157
	8	1.96	1176	784	588	470	392	336	294	261	235	196	168
	9	2.08	1248	832	624	498	416	356	312	277	249	208	178
	10	2.19	1316	876	658	526	438	376	329	292	263	219	188
	2	1.31	784	524	392	314	262	224	196	175	157	131	112
	3	1.6	960	640	480	384	320	274	240	213	192	160	137
	4	1.85	1108	740	554	444	370	316	277	247	222	185	158
	5	2.07	1240	828	620	496	414	354	310	276	248	207	177
04	6	2.26	1356	904	678	544	452	388	339	301	272	226	194
	7	2.44	1468	976	734	586	488	418	367	325	293	244	209
	8	2.61	1568	1044	784	626	522	448	392	348	313	261	224
	9	2.77	1664	1108	832	666	554	476	416	369	333	277	238
	10	2.92	1752	1168	876	702	584	500	438	389	351	292	250
	2	1.63	980	652	490	392	326	280	245	217	196	163	140
	3	2	1200	800	600	480	400	342	300	267	240	200	171
	4	2.31	1384	924	692	554	462	396	346	308	277	231	198
	5	2.58	1548	1032	774	620	516	442	387	344	310	258	221
05	6	2.83	1696	1132	848	678	566	484	424	377	339	283	242
	7	3.06	1832	1224	916	734	612	524	458	408	367	306	262
	8	3.26	1960	1304	980	784	652	560	490	435	392	326	280
	9	3.46	2080	1384	1040	832	692	594	520	461	416	346	297
	10	3.65	2192	1460	1096	876	730	626	548	487	438	365	313
	2	1.96	1568	784	784	470	392	336	392	261	235	196	168
	3	2.4	1920	960	960	576	480	412	480	320	288	240	206
	4	2.77	2216	1108	1108	666	554	476	554	369	333	277	238
	5	3.1	2480	1240	1240	744	620	532	620	413	372	310	266
06	6	3.39	2716	1356	1358	814	678	582	679	452	407	339	291
	7	3.67	2932	1468	1466	880	734	628	733	489	440	367	314
	8	3.92	3136	1568	1568	940	784	672	784	523	470	392	336
	9	4.16	3324	1664	1662	998	832	712	831	555	499	416	356
	10	4.38	3504	1752	1752	1052	876	752	876	584	526	438	376
	2	2.61	1568	1044	784	628	522	448	392	348	314	261	224
	3	3.2	1920	1280	960	768	640	548	480	427	384	320	274
	4	3.7	2216	1480	1108	886	740	634	554	493	443	370	317
	5	4.13	2480	1652	1240	992	826	708	620	551	496	413	354
08	6	4.53	2716	1812	1358	1086	906	776	679	604	543	453	388
	7	4.89	2932	1956	1466	1174	978	838	733	652	587	489	419
	8	5.22	3136	2088	1568	1254	1044	896	784	696	627	522	448
	9	5.54	3324	2216	1662	1330	1108	950	831	739	665	554	475
	10	5.84	3504	2336	1752	1402	1168	1002	876	779	701	584	501

Flow rate

$$\text{L/min/nozzle} = \frac{\text{L/ha x km/h x W(m)}}{600}$$

Example

A grower wants to spray **400 L/ha**, drive with a speed of **6 km/h** and the boom has a nozzle spacing of **50 cm**

$$\text{L/min} = \frac{\text{400 L/ha x 6 km/h x 0.5 m}}{600} = \text{2.0 L/min}$$

The grower needs to us a nozzle that delivers **2.0 L/min**. For example, the grower could use an **04 nozzle size at 4.5 bar or an 05 size at 3 bar** (see table).

L/min/nozzle	= nozzle flow rate in litre per minute
L/ha	= water application rate per hectare
Km/h	= driving speed
W	= width of nozzle spacing in m
600	= constant

Application rate

$$\text{Application rate (L/ha)} = \frac{\text{L/min/nozzle x 600}}{\text{km/h x W(m)}}$$

Banding/Directed application

The above formulas can still be used but W becomes the row spacing (m) divided by the number of nozzles per row. For example, **2 nozzles** are centered towards a hilled vegie crop with a row spacing of **1.5 m. W = 1.5/2 = 0.75**

Pressure

1 bar (bar)
= 100 kilopascal (kPa)
= 14.5 pound per square inch (PSI)

1 pound per square inch (PSI)
= 6.89 kilopascal (kPa)
= 0.0689 bar (bar)

As a rule of thumb, to double the flow through a nozzle, the pressure must be increased four times. Higher pressures increase drift (less so for AI nozzles) and increase the rate of orifice wear.

Travel Speed

$$\text{Speed (km/h)} = \frac{\text{Distance (m) x 3.6}}{\text{Time (sec)}}$$

For accurate application it is important to calibrate the speed of the tractor. An easy way to do so is to drive in the gear the application will be done in, measure the time it takes to travel **100 m** and apply this simple formula. For example, it takes the grower **60 sec** to drive **100 m**. The application speed is **6 km/h**.

$$\text{Speed (km/h)} = \frac{\text{100m x 3.6}}{\text{60 sec}} = \text{6 km/h}$$

Nozzle spacing	25 cm spacing	30 cm spacing	35 cm spacing	40 cm spacing	45 cm spacing
Conversion factor	2	1.66	1.43	1.25	1.11

This 50 cm nozzle spacing table can still be used for booms with different nozzle spacing by using the above conversion factors.

For example, if pressure and speed are given, the L/ha value for 30 cm spacing can be calculated by multiplying the given L/ha table value by 1.66.

And the other way around.

For example, a grower wants to use 400 L/ha. The boom nozzle spacing is 30 cm. To use this table he needs to divide 400 L/ha by the 30 cm conversion factor (= 1.66). 400 L/ha / 1.66 = 241 L/ha = a 241 L/ha value in this 50 cm spacing table reflects a 400 L/ha value for 30 cm spacing.

Figure 81

SELECTING NOZZLES FOR BOOM APPLICATIONS

SPRAY QUALITY

Nufarm SprayWise®

Nozzle selection is often based upon droplet size. The droplet size from a nozzle becomes very important when the efficacy of a particular crop chemical is dependent on coverage, or the prevention of spray leaving the target area is a priority.

VF	F	M	C	VC	XC
VERY FINE	FINE	MEDIUM	COARSE	VERY COARSE	EXTREMELY COARSE

NOTE: COLOUR CODING FOR SPRAY QUALITIES ARE NOT RELATED TO COLOUR CODING FOR NOZZLE SIZES

Spray quality classifications are based on BCPC specifications and are in accordance with ASAE Standard S-572 at the date of printing. Classifications are subject to change.

An important point to remember when choosing a spray nozzle that produces a droplet spectra in one of the six categories, is that one nozzle can produce different droplet spectra classifications at different pressures. A nozzle might produce MEDIUM droplets at low pressures, while producing FINE droplets as pressure is increased. Note: Always double check your application rates.

Conventional

agrotop TipCap

	BAR					
	1.5	2	2.5	3	3.5	4
TCP 11001	VF	VF	VF	VF	VF	VF
TCP 110015	F	VF	VF	VF	VF	VF
TCP 11002	F	F	F	F	F	F
TCP 110025	F	F	F	F	F	F
TCP 11003	F	F	F	F	F	F
TCP 11004	F	F	F	F	F	F

ALBUZ® AXI 110 — UPGRADE TO CERAMIC

	BAR				
	1.5	2	2.5	3	4
AXI 110015	F	F	F	F	F
AXI 11002	F	F	F	F	F
AXI 110025	M	M	M	M	F
AXI 11003	M	M	M	M	M
AXI 11004	M	M	M	M	M

Low Drift

Turbo TeeJet®

	Bar							
	1.5	2	2.5	3	3.5	4	4.5	5
TT11001	M	M	M	F	F	F	F	F
TT110015	C	M	M	M	M	M	F	F
TT11002	C	C	M	M	M	M	M	M
TT110025	C	C	C	M	M	M	M	M
TT11003	C	C	C	C	M	M	M	M
TT11004	C	C	C	C	C	C	M	M

ALBUZ® ADI 110 — UPGRADE TO CERAMIC

	BAR				
	2	2.5	3	3.5	4
ADI 11001	M	M	M	F	F
ADI 110015	M	M	M	M	M
ADI 11002	M	M	M	M	M
ADI 11003	C	M	M	M	M
ADI 11004	VC	C	C	C	C

Low Pressure Air Induction

agrotop AirMix®

	Bar								
	2	2.5	3	3.5	4	4.5	5	5.5	6
AM11001	M	M	M	M	F	F	F	F	F
AM110015	XC	VC	C	C	C	C	C	C	M
AM11002	C	C	C	C	M	M	M	M	M
AM110025	VC	C	C	C	C	C	M	M	M
AM11003	VC	VC	C	C	C	C	C	C	M
AM11004	VC	VC	C	C	C	M	M	M	M

ALBUZ® CVI 110 — UPGRADE TO CERAMIC

	BAR						
	2	2.5	3	3.5	4	4.5	5
CVI 110015	C	C	C	C	C	C	C
CVI 11002	C	C	C	C	C	C	M
CVI 110025	C	C	C	C	C	C	M
CVI 11003	C	C	C	C	C	C	M
CVI 11004	C	C	C	C	C	M	M

High Pressure Air Induction

agrotop TurboDrop® TD — UPGRADE TO CERAMIC

	Bar								
	4	4.5	5	5.5	6	6.5	7	7.5	8
TD 110 015	C	C	C	C	C	C	C	C	C
TD 110 02	C	C	C	C	C	C	C	C	C
TD 110 025	VC	VC	VC	VC	VC	VC	VC	VC	VC
TD 110 03	VC	C	C	C	C	C	C	C	C
TD 110 04	VC	VC	VC	VC	VC	VC	C	C	C

Nufarm data supported by agrotop. This information supersedes data on previous versions distributed; Data for AM11004 - agrotop

ALBUZ® AVI 110 — UPGRADE TO CERAMIC

	BAR						
	3	4	5	5	6	7	8
AVI 11001	VC	C	C	C	C	C	C
AVI 110015	VC	C	C	C	C	C	C
AVI 11002	VC	C	C	C	C	C	C
AVI 110025	VC	C	C	C	C	C	C
AVI 11003	XC	C	C	C	C	C	C
AVI 11004	XC	VC	VC	VC	VC	VC	VC

EXTREMELY COARSE

agrotop XC TurboDrop®

	BAR				
	3	4	5	6	7
XC TD-110015	XC	XC	XC	XC	VC
XC TD-11002	XC	XC	XC	XC	VC
XC TD-110025	XC	XC	XC	XC	XC
XC TD-11003	XC	XC	XC	XC	XC
XC TD-11004	XC	XC	XC	XC	XC

Figure 82

SELECTING NOZZLES FOR BOOM APPLICATIONS

ATR HOLLOW CONE FLOWRATE CHART

Pressure		L/min									
		White	Lilac	Brown	Yellow	Orange	Red	Grey	Green	Black	Blue
Bar	5	0.27	0.36	0.48	0.73	0.99	1.38	1.5	1.78	2	2.45
	6	0.29	0.39	0.52	0.8	1.08	1.51	1.63	1.94	2.18	2.67
	7	0.32	0.42	0.56	0.86	1.17	1.62	1.76	2.09	2.35	2.87
	8	0.34	0.45	0.6	0.92	1.24	1.73	1.87	2.22	2.5	3.06
	9	0.36	0.48	0.64	0.97	1.32	1.83	1.98	2.35	2.64	3.24
	10	0.38	0.5	0.67	1.03	1.39	1.92	2.08	2.47	2.78	3.4
	11	0.39	0.52	0.7	1.07	1.45	2.01	2.17	2.58	2.9	3.56
	12	0.41	0.55	0.73	1.12	1.51	2.09	2.26	2.69	3.03	3.71
	13	0.43	0.57	0.76	1.17	1.57	2.17	2.35	2.79	3.14	3.85
	14	0.44	0.59	0.79	1.21	1.63	2.25	2.43	2.89	3.26	3.99
	15	0.46	0.61	0.81	1.25	1.69	2.33	2.51	2.99	3.36	4.12
	16	0.47	0.63	0.84	1.29	1.74	2.4	2.59	3.08	3.47	4.25
ALBUZ Equivalent*	TVI	Purple 80-0050	Pink 80-0075	Orange 80-01	Green 80-015	Yellow 80-02	Lilac 80-025	Blue 80-03	Blue 80-03	Red 80-03	Red 80-03
TeeJet Equivalent*	TX	TX-VK3	TX-VK4	TX-VK6	TX-VK8	TX-VK12	TX-VK18	TX-VK18	TX-VK18	TX-VK26	TX-VK26
	TXB80	TXB-050VK	TXB-067VK	TXB-01VK	TXB-015VK	TXB-02VK	TXB-03VK	TXB-03VK	TXB-03VK	TXB-04VK	TXB-04VK

Note: Colours in table represent actual nozzle colour. ALBUZ® TVI and TXB80 TeeJet® nozzle range are ISO colour coded. Nozzles with the same colour have the same output. The ALBUZ® ATR and TeeJet® TX range are NOT ISO colour coded. Their nozzle colour is not related to a specific output.

Figure 83

DISC AND CORE ALBUZ CERAMIC – FLOWRATES

Disc SIZE	Core SIZE	Orifices Diameter	L/min							Angles	
			3 bar	4 bar	5 bar	6 bar	10 bar	15 bar	20 bar	10 bar	20 bar
AD 1	AC 13	0.910	0.28	0.29	0.32	0.34	0.43	0.51	0.57	66°	68°
AD 2	AC 13	1.180	0.32	0.37	0.40	0.42	0.52	0.63	0.67	74°	75°
AD 3	AC 13	1.385	0.36	0.41	0.43	0.48	0.60	0.71	0.74	77°	78°
AD 4	AC 13	1.810	0.47	0.52	0.58	0.60	0.74	0.91	1.00	84°	85°
AD 1	AC 23	0.910	0.28	0.30	0.35	0.38	0.48	0.55	0.61	63°	65°
AD 2	AC 23	1.180	0.39	0.48	0.50	0.56	0.71	0.83	0.93	72°	72°
AD 3	AC 23	1.385	0.47	0.52	0.58	0.64	0.78	0.95	1.04	77°	77°
AD 4	AC 23	1.810	0.59	0.71	0.76	0.81	1.04	1.26	1.41	88°	87°
AD 5	AC 23	2.310	0.71	0.82	0.90	0.99	1.27	1.50	1.71	96°	95°
AD 6	AC 23	2.770	0.83	0.97	1.04	1.13	1.45	1.78	2.01	100°	99°
AD 1	AC 25	0.910	0.40	0.45	0.50	0.55	0.69	0.83	0.95	49°	51°
AD 2	AC 25	1.180	0.63	0.71	0.79	0.88	1.08	1.34	1.53	61°	61°
AD 3	AC 25	1.385	0.75	0.86	0.94	1.02	1.30	1.58	1.79	69°	69°
AD 4	AC 25	1.810	1.14	1.30	1.44	1.59	2.01	2.45	2.79	82°	82°
AD 5	AC 25	2.310	1.36	1.56	1.73	1.91	2.42	2.96	3.35	85°	84°
AD 6	AC 25	2.770	1.74	2.01	2.23	2.47	3.16	3.83	4.43	89°	88°
AD 7	AC 25	3.230	2.05	2.34	2.63	2.86	3.85	4.66	5.10	92°	91°
AD 1	AC 45	0.910	0.49	0.55	0.61	0.67	0.84	1.01	1.15	39°	40°
AD 2	AC 45	1.180	0.79	0.93	1.01	1.13	1.41	1.74	1.97	58°	58°
AD 3	AC 45	1.385	0.91	1.04	1.19	1.27	1.84	2.01	2.31	62°	63°
AD 4	AC 45	1.810	1.42	1.60	1.80	1.98	2.53	3.08	3.54	73°	72°
AD 5	AC 45	2.310	1.78	2.05	2.31	2.51	3.20	3.91	4.54	76°	75°
AD 6	AC 45	2.770	2.29	2.68	2.99	3.28	4.28	5.25	6.10	80°	79°
AD 7	AC 45	3.230	2.68	3.13	3.50	3.92	5.02	6.20	7.22	86°	85°
AD 1	AC 46	0.910	0.57	0.66	0.74	0.81	1.04	1.26	1.45	17°	17°
AD 2	AC 46	1.180	1.07	1.23	1.33	1.48	1.86	2.25	2.53	20°	18°
AD 3	AC 46	1.385	1.26	1.45	1.62	1.80	2.27	2.76	3.20	23°	21°
AD 4	AC 46	1.810	2.21	2.53	2.81	3.11	3.98	4.85	5.86	32°	31°
AD 5	AC 46	2.310	3.04	3.50	3.96	4.41	5.58	6.83	7.93	41°	40°
AD 6	AC 46	2.770	4.34	5.02	5.69	6.11	8.04	9.87	11.39	49°	47°
AD 7	AC 46	3.230	5.49	6.40	7.10	7.84	10.16	12.43	14.33	55°	53°
AD 1	AC 31	0.910	–	–	–	–	0.92	1.10	1.25	39°	39°
AD 2	AC 31	1.180	–	–	–	–	1.41	1.69	1.92	87°	95°
AD 3	AC 31	1.385	–	–	–	–	1.50	1.80	2.05	65°	62°
AD 1	AC 35	0.910	–	–	–	–	0.92		1.25	34°	40°
AD 2	AC 35	1.180	–	–	–	–	1.58	1.90	2.16	39°	39°
AD 3	AC 35	1.385	–	–	–	–	2.20	2.64	3.00	44°	42°
AD 4	AC 35	1.810	–	–	–	–	3.58	4.30	4.89	77°	72°
AD 5	AC 35	2.310	2.60	3.00	3.30	3.60	4.51	5.41	6.16	37°	34°
AD 2	AC 56	1.180	0.98	1.10	1.20	1.40	1.52	1.82	2.07	21°	20°
AD 3	AC 56	1.385	1.30	1.60	1.70	1.90	2.05	2.46	2.80	28°	32°
AD 4	AC 56	1.810	2.20	2.50	2.80	3.10	3.52	4.23	4.81	35°	38°
AD 5	AC 56	2.310	3.00	3.50	3.90	4.30	5.96	7.15	8.14	43°	40°
AD 6	AC 56	2.770	4.50	5.30	5.90	6.50	8.78	10.54	12.00	56°	49°
AD 7	AC 56	3.230	6.00	6.90	7.70	8.50	11.80	14.17	16.20	68°	64°

Figure 84

SELECTING NOZZLES FOR BOOM APPLICATIONS

2. NOZZLE TYPE

After working out the potential nozzle size and corresponding pressure, it is time to pick the appropriate nozzle type to produce the desired spray quality. In the potato example, it is most likely that applications will be carried out with fungicides and insecticides. Unless operating in a very windy location, the grower would most likely choose a FINE or MEDIUM spray quality. Tables on pages 48 - 49 will assist in finding nozzles producing this spray quality.

1. The first option was a blue 03 size nozzle at 8.5 bar. The only flat fan nozzles that should be used at that pressure are high-pressure air induction nozzles producing a COARSE to VERY COARSE spray quality
2. The second option was a red 04 size at 4.6 bar which would fit the pressure requirements for a low-pressure air induction nozzle that can produce a MEDIUM spray quality
3. The last flat fan option was a brown 05 size at 3 bar. Pre-orifice nozzles at that size would produce a COARSE spray quality. The other option would be a conventional nozzle producing a MEDIUM spray quality.
4. Regardless of choice, all three hollow cone nozzle options will produce a FINE spray quality (Figure 87). The amount of driftable fines will increase with pressure

Given the parameters 300 L/ha, 8 km/h and FINE to MEDIUM spray quality the best nozzle options for the example are (in order of coarsest to finest)

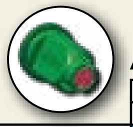
1. Red 04 low-pressure air-induction nozzle such as ALBUZ® CVI at 4.6 bar = MEDIUM (Figure 85)
2. Brown 05 conventional nozzle such as ALBUZ® AXI at 3 bar = MEDIUM (Figure 86)
3. Hollow cone nozzles such as ATR sizes green, grey and red at 6.5, 9 and 11 bar = FINE (Figure 87)

SELECTING NOZZLES FOR BANDSPRAYING

Band-spraying is common practice in horticultural situations. Rather than broadcasting a chemical over an entire area, only selective bands are targeted. Examples would be herbicide applications under vine or tree crops, herbicide applications in between sugar cane rows or fungicide applications over hilled vegetable rows.

For nozzle selection, the same principles apply as for broadcast spraying. The same formula can be used (L/min/nozzle = L/ha x km/h x W(m) ÷ 600). The only variation is that W (width between nozzles) becomes the width of the band divided by the number of nozzles.

HEADING

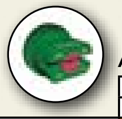


ALBUZ®8 CVI 110

	BAR						
	2	2.5	3	3.5	4	4.5	5
CVI 110015	C	C	C	C	C	C	C
CVI 11002	C	C	C	C	C	C	M
CVI 110025	C	C	C	C	C	C	M
CVI 11003	C	C	C	C	C	C	M
CVI 11004	C	C	C	C	C	M	M

Figure 85

HEADING

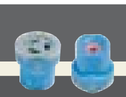


ALBUZ®8 AXI 110

	BAR				
	1.5	2	2.5	3	4
AXI 110015	F	F	F	F	F
AXI 11002	F	F	F	F	F
AXI 110025	M	M	M	M	F
AXI 11003	M	M	M	M	M
AXI 11004	M	M	M	M	M
AXI 11005	M	M	M	M	M

Figure 86

ATR HOLLOW CONE FLOWRATE CHART



PRESSURE	L/MIN									
BAR	White	Lilac	Brown	Yellow	Orange	Red	Grey	Green	Black	Blue
5	0.27	0.36	0.48	0.73	0.99	1.38	1.5	1.76	2	2.45
6	0.29	0.39	0.52	0.8	1.08	1.51	1.63	1.94	2.18	2.67
7	0.32	0.42	0.56	0.86	1.17	1.62	1.76	2.09	2.35	2.87
8	0.34	0.45	0.6	0.92	1.24	1.73	1.87	2.22	2.5	3.06
9	0.36	0.48	0.64	0.97	1.32	1.83	1.98	2.35	2.64	3.24
10	0.38	0.5	0.67	1.03	1.39	1.92	2.08	2.47	2.78	3.4
11	0.39	0.52	0.7	1.07	1.45	2.01	2.17	2.58	2.9	3.56
12	0.41	0.55	0.73	1.12	1.51	2.07	2.26	2.69	3.03	3.71
13	0.43	0.57	0.76	1.17	1.57	2.17	2.35	2.79	3.14	3.85
14	0.44	0.59	0.79	1.21	1.63	2.25	2.43	2.89	3.26	3.99
15	0.46	0.61	0.81	1.25	1.69	2.33	2.51	2.99	3.36	4.12
16	0.47	0.63	0.84	1.29	1.74	2.4	2.59	3.08	3.47	4.25
ALBUZ® Equivalent* TVI	Purple 80–0050	Pink 80–0075	Orange 80–01	Green 80–015	Yellow 80–02	Lilac 80–025	Blue 80–03	Blue 80–03	Red 80–03	Red 80–03
TeeJet Equivalent* TX	TX-VK3	TX-VK4	TX-VK6	TX-VK8	TX-VK12	TX-VK18	TX-VK18	TX-VK18	TX-VK26	TX-VK26
TeeJet Equivalent* TXB80	TXB-050VK	TXB-067VK	TXB-01VK	TXB-015VK	TXB-02VK	TXB-03VK	TXB-03VK	TXB-03VK	TXB-04VK	TXB-04VK

Note: Colours in table represent actual nozzle colour. ALBUZ® TVI and TXB80 TeeJet® nozzle range are ISO colour coded. Nozzles with the same colour have the same output. The ALBUZ® ATR and TeeJet® TX range are NOT ISO colour coded. Their nozzle colour is not related to a specific output.

Figure 87

BAND SPRAYING EXAMPLE 1

A vegetable grower sprays 0.8 m wide bands using 4 nozzles, 2 over-head and 2 side-on. They apply 250 L/ha with a speed of 5 km/h. W (width) becomes 0.8 m / 4 nozzles = 0.2 m.

L/min/nozzle = 250 L/ha x 5 km/h x 0.2 m ÷ 600 = 0.42 L/min/nozzle.

The grower needs to use nozzles with an output of 0.42 L/min (e.g. ALBUZ® ATR lilac at 7 bar).

If the grower prefers not to put out the same volume through the four nozzles they can be calculated easily too as long as the overall output of the four nozzles stays the same. The four nozzles need to apply a total of 1.68 L/min (4 x 0.42 L/min). As long as this total is achieved, the application criteria (250 L/ha, 5 km/h) will be met. For example, the two over-head nozzles could be used to achieve an output of 0.48 L/min each (e.g. ALBUZ® ATR brown at 5 bar) with the two side-nozzles producing an output of 0.36 L/min (e.g. ALBUZ® ATR lilac at 5 bar)(0.48 + 0.48 + 0.36 + 0.36 = 1.68 L/min).

When matching different sized nozzles that produce different outputs, it is vital that output volumes are matched at the same corresponding pressure. Different nozzle sizes still have to operate at the same pressure next to each other.

BAND-SPRAYING EXAMPLE 2

In a vineyard herbicide application, the aim is to spray 60 cm wide bands on each side of the vine. Two off-centre nozzles are covering the band. The application rate is 250 L/ha at 6 km/h. W (width) becomes 0.3 m (0.6 m/2 nozzles).

L/min/nozzle = 250 L/ha x 6 km/h x 0.3 m ÷ 600 = 0.75 L/min.

The grower needs to use off-center nozzles that apply 0.75 L/min, e.g. agrotop AirMix® 02 OC around 2.7 bar.

EFFECT OF NOZZLE HEIGHT ON DRIFT

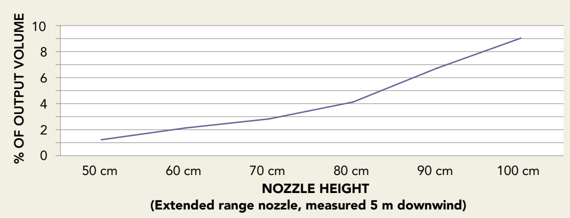


Figure 88 Source: Paul Miller (Silsoe, England)

SELECTING NOZZLES FOR SPOT-SPRAYING

Calibration in spot-spraying is not important. The chemicals are mixed on a per 100 L base and flooded over the target above the point of run-off. Little precision is required. The volume is achieving the coverage. The coarser the spray-quality, the lower the risk of drift.

BOOM SET-UP: SPACING AND HEIGHT

The critical factor in nozzle spacing and height is to achieve a double overlap of nozzle spray patterns. Typically for 110° flat fan nozzles with a 50 cm spacing this is achieved at 50 cm height. The boom height is measured between the nozzle tip and the top of the target, not the bottom. That can be difficult in situations with tall weeds and limited possibilities for raising the boom, such as contact herbicide spraying under vines. Any other none target object that interferes with the spray pattern such as stubbles (false target - Figure 89) must be addressed in the same way. The distance from nozzle tip to false target tip should be 50 cm.

One possibility to reduce this difficulty is to decrease nozzle spacing to 25 cm. Overlap is achieved earlier and height can be reduced. Another consideration for keeping the nozzles as low as possible is to reduce drift. Doubling the height produces more than 4 times more drift. (Figure 88). Nozzles with smaller angles should be run at a higher distance from the target.

CHANGING APPLICATION HEIGHT WITH FALSE TARGET

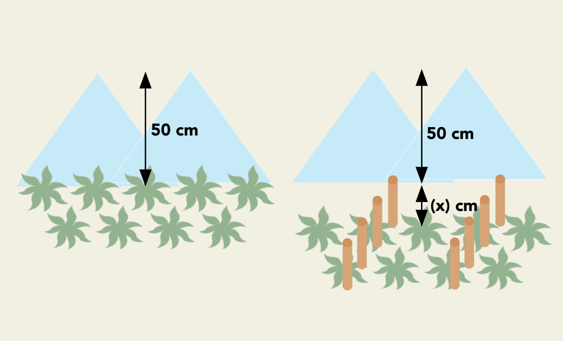


Figure 89

SELECTING NOZZLES FOR TREE AND VINE SPRAYING

CHAPTER SUMMARY

As in boom spray application, nozzle selection for tree and vine spraying is mainly governed by:

- Speed
- Water volume
- Spray quality

The L/100 m distance based calibration method is the easiest way to work out required nozzle flow rates.

The required water volume, the speed and application pressure determine the size of nozzles used. The tables on pages 49 and 56 allow in 3 easy steps to find the nozzles needed. The process highlights the practicality of using the L/100 m approach:

1. Translate the desired volume into L/100 m if not already done so (see page 26)
2. In combination with speed, work out the required pump output in L/min
3. Divide the total output by number of nozzles to obtain the individual nozzle flow rate

Following are three examples for grape vines, apples and citrus to demonstrate how to use the charts. For each example a different colour is used to follow the steps through the tables. The procedure can be used for any desired application volume; dilute or concentrate. The procedure works on a per row base even if two or three row sprayers are used.

For transforming L/100 m into L/tree, see page 26.

GRAPE VINES - EXAMPLE

Table 1 on (Figure 90, page 53) shows the relationship between row spacing (on top), L/ha (on left) and the corresponding L/100 m value. The L/100 m is the value needed to proceed to the next step. At 3 m row spacing the sprayer needs to put out 30 L every 100 m of row to produce 1000 L/ha.

Table 2 (see page 54) allows to find the needed flowrate for the pump. The numbers in the table represent L/100 m. In this example we need to follow down the 8 km/h column until we reach 30 L/100 m or the nearest number (Figure 91). To the left we find the corresponding L/min total pump output. In our example the pump needs to produce a flow of 40 L/min per row. The faster we drive the higher the needed flow rate is to keep the output constant at 30 L/100 m.

The last step is to divide the total flow rate by the number of nozzles per row to find the individual nozzle output. In this example a Croplands Quantum Mist™ sprayer is used with 4 heads per row containing 6 nozzles each. Simply dividing 40 L/min pump output by 24 nozzles = 1.66 L/min. We need nozzles that produce a flow rate of 1.66 L/min. Table 3 (Figure 83, page 49) displays flow rates of different hollow cone nozzle sizes and the corresponding pressure needed. 1.66 L/min is produced by an orange ATR around 14 bar, a red ATR around 7 bar and a grey ATR at 6 bar (Table 3, page 54). Different brands are shown at the bottom of the table. Be aware that not all hollow cone nozzles are ISO colour coded. Read the note on the bottom of the table.

If different sized nozzles are used during the same application, the overall flow rate for all nozzles needs to stay the same. For example, rather than having 24 identical nozzles putting out 40 L/min some may choose to have 12 nozzles putting out 17 L and 12 nozzles putting out 23 L/min. The overall flow rate remains at 40 L/min. At 10 bar an orange ATR would produce a flow of 1.39 L/min and a red ATR of 1.92 L/min, the average of the two sizes being close to the required 1.66 L/min.

VINES - EXAMPLE

- 1.5 m canopy = 30 L/100m (20 L x 1.5)
- Croplands Quantum Mist™
  4 heads x 6 nozzles = 24 nozzles
- 3m row spacing
- Speed = 8 km/h

RESULTS

Table 1 1000 L/ha
Table 2 40 L/min
Table 3 1.66 L/min

APPLES - EXAMPLE

In this example (blue) a grower drives at 8 km/h using a Croplands Quantum Mist™ apple tower with 6 heads per row, each containing 6 nozzles = 36 nozzles per row. The row spacing is 4 m and the canopy 3 m high. The Dilute Volume is around 60 L/100 m (3 x 20) or at this row spacing equal to 1500 L/ha (Table 1, Figure 90, page 53). At 8 km/ha the pump will need to produce a total flow rate of 80 L/min (Table 2, page 54). The flowrate for each of the 36 nozzles needs to be 2.2 L/min. This could be achieved with a red ATR at 14 bar, a grey ATR at 12 bar or a green one at 8 bar (Table 3, figure 92, page 54). For a mixture of sizes the green and grey ATRs at around 9.5 bar would achieve a similar average output:

- 3 m canopy = 60 L/ 100 m (20 L x 3)
- Croplands Quantum Mist™
  6 heads x 6 nozzles = 36 nozzles
- 4 m row spacing
- Speed = 8 km/h

RESULTS

Table 1 1500 L/ha
Table 2 80 L/min
Table 3 2.2 L/min

CITRUS - EXAMPLE

The last example is a citrus scenario. The water volume for the medium dense 4 m high canopy is 160 L/100 m (4 x 40) or 2000 L/ha for 8 m row spacing. The tractor speed is 4.5 km/hour. The sprayer is a Croplands Quantum Mist™ citrus tower with 8 heads each containing 6 nozzles = 48 nozzles. The pump needs to produce 120 L/min. That equals 2.5 L/min for each of the 48 nozzles. Possible choices would be the red ATR size at 17 bar, the grey size at 15 bar, green at 10 bar or black ATRs at 8 bar. A possible mixing size would be the red and green ATRs just above 13 bar:

- 4 m canopy = 160 L/ 100 m (40 L x 4)
- Croplands Quantum Mist™
  8 heads x 6 nozzles = 48 nozzles
- 8 m row spacing
- Speed = 4.5 km/h

RESULTS

Table 1 2000 L/ha
Table 2 120 L/min
Table 3 2.5 L/min

HEADING

1

L/ha ⟷ L/100 m — Table unit = L/100 m

L/ha \ Row Spacing (m)	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
100	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
150	2.4	2.7	3	3.1	3.6	3.8	4	4.2	4.4	4.5	4.7	4.8	5	5.3	5.4	6	6.8	7.5	8.3	9	9.8	10.5	11.3	12	12.8	13.5	15
200	3.2	3.6	4	4.2	4.8	5	5.4	5.6	5.8	6	6.2	6.4	6.7	7	7.2	8	9	10	11	12	13	14	15	16	17	18	20
250	4	4.5	5	5.2	6	6.3	6.7	7	7.3	7.5	7.8	8	8.3	8.8	9.0	10	11.3	12.5	13.8	15	16.3	17.5	18.8	20	21	23	25
300	4.8	5.4	6	6.3	7.1	7.5	8.1	8.4	8.7	9	9.3	9.6	10	10.5	10.8	12	13.5	15	16.5	18	19.5	21	23	24	26	27	30
350	5.6	6.3	7	7.3	8.3	8.8	9.4	9.8	10.2	10.5	10.9	11.2	11.7	12.3	12.6	14	15.8	17.5	19.3	21	23	25	26	28	30	32	35
400	6.4	7.2	8	8.3	9.5	10	10.8	11.2	11.6	12	12.4	12.8	13.3	14	14.4	16	18	20	22	24	26	28	30	32	34	36	40
450	7.2	8.1	9	9.4	11	11.3	12.1	12.6	13.1	13.5	14	14.4	15	15.8	16.2	18	20	23	25	27	29	32	34	36	38	41	45
500	8	9	10	10	12	12.5	13.5	14	14.5	15	15.5	16	16.7	17.5	18	20	23	25	28	30	33	35	38	40	43	45	50
600	9.6	10.8	12	13	14	15	16.2	16.8	17.4	18	18.6	19.2	20	21	22	24	27	30	33	36	39	42	45	48	51	54	60
700	11.2	12.6	14	15	17	17.5	18.9	19.6	20	21	22	22	23	25	25	28	32	35	39	42	46	49	53	56	60	63	70
750	12	13.5	15	16	18	18.8	20	21	22	23	23	24	25	26	27	30	34	38	41	45	49	53	56	60	64	68	75
800	12.8	14.4	16	17	19	20	22	22	23	24	25	26	27	28	29	32	36	40	44	48	52	56	60	64	68	72	80
900	14.4	16.2	18	19	21	23	24	25	26	27	28	29	30	32	32	36	41	45	50	54	59	63	68	72	77	81	90
1000	16	18	20	21	24	25	27	28	29	30	31	32	33	35	36	40	45	50	55	60	65	70	75	80	85	90	100
1100	17.6	19.8	22	23	26	28	30	31	32	33	34	35	37	39	40	44	50	55	61	66	72	77	83	88	94	99	110
1200	19.2	22	24	25	29	30	32	34	35	36	37	38	40	42	43	48	54	60	66	72	78	84	90	96	102	108	120
1300	21	23	26	27	31	33	35	36	38	39	40	42	43	46	47	52	59	65	72	78	85	91	98	104	111	117	130
1400	22	25	28	29	33	35	38	39	41	42	43	45	47	49	50	56	63	70	77	84	91	98	105	112	119	126	140
1500	24	27	30	31	36	38	40	42	44	45	47	48	50	53	54	60	68	75	83	90	98	105	113	120	128	135	150
1600	26	29	32	33	38	40	43	45	46	48	50	51	53	56	58	64	72	80	88	96	104	112	120	128	136	144	160
1700	27	31	34	35	40	43	46	48	49	51	53	54	57	60	61	68	77	85	94	102	111	119	128	136	145	153	170
1800	29	32	36	38	43	45	49	50	52	54	56	58	60	63	65	72	81	90	99	108	117	126	135	144	153	162	180
1900	30	34	38	40	45	48	51	53	55	57	59	61	63	67	68	76	86	95	105	114	124	133	143	152	162	171	190
2000	32	36	40	42	48	50	54	56	58	60	62	64	67	70	72	80	90	100	110	120	130	140	150	160	170	180	200
2500	40	45	50	52	60	63	67	70	73	75	78	80	83	88	90	100	113	125	138	150	163	175	188	200	213	225	250
3000	48	54	60	63	71	75	81	84	87	90	93	96	100	105	108	120	135	150	165	180	195	210	225	240	255	270	300
4000	64	72	80	83	95	100	108	112	116	120	124	128	133	140	144	160	180	200	220	240	260	280	300	320	340	360	400
5000	80	90	100	104	119	125	135	140	145	150	155	160	167	175	180	200	225	250	275	300	325	350	375	400	425	450	500
6000	96	108	120	125	143	150	162	168	174	180	186	192	200	210	216	240	270	300	330	360	390	420	450	480	510	540	600
7000	112	126	140	146	167	175	189	196	203	210	217	224	233	245	252	280	315	350	385	420	455	490	525	560	595	630	700
8000	128	144	160	167	190	200	216	224	232	240	248	256	266	280	288	320	360	400	440	480	520	560	600	640	680	720	800
9000	144	162	180	188	214	225	243	252	261	270	279	288	300	315	324	360	405	450	495	540	585	630	675	720	765	810	900
10000	160	180	200	208	238	250	270	280	290	300	310	320	333	350	360	400	450	500	550	600	650	700	750	800	850	900	1000
Conversion Factor	62.5	55.5	50	47.6	41.7	40	37.0	35.7	34.5	33.3	32.3	31.3	30.3	28.6	27.8	25	22.2	20	18.2	16.7	15.4	14.3	13.3	12.5	11.8	11.1	10

Formula: L/100 m = L/ha ÷ 100 x row spacing (m) — L/ha = L/100 m x 100 ÷ row spacing (m)

Figure 90

HEADING

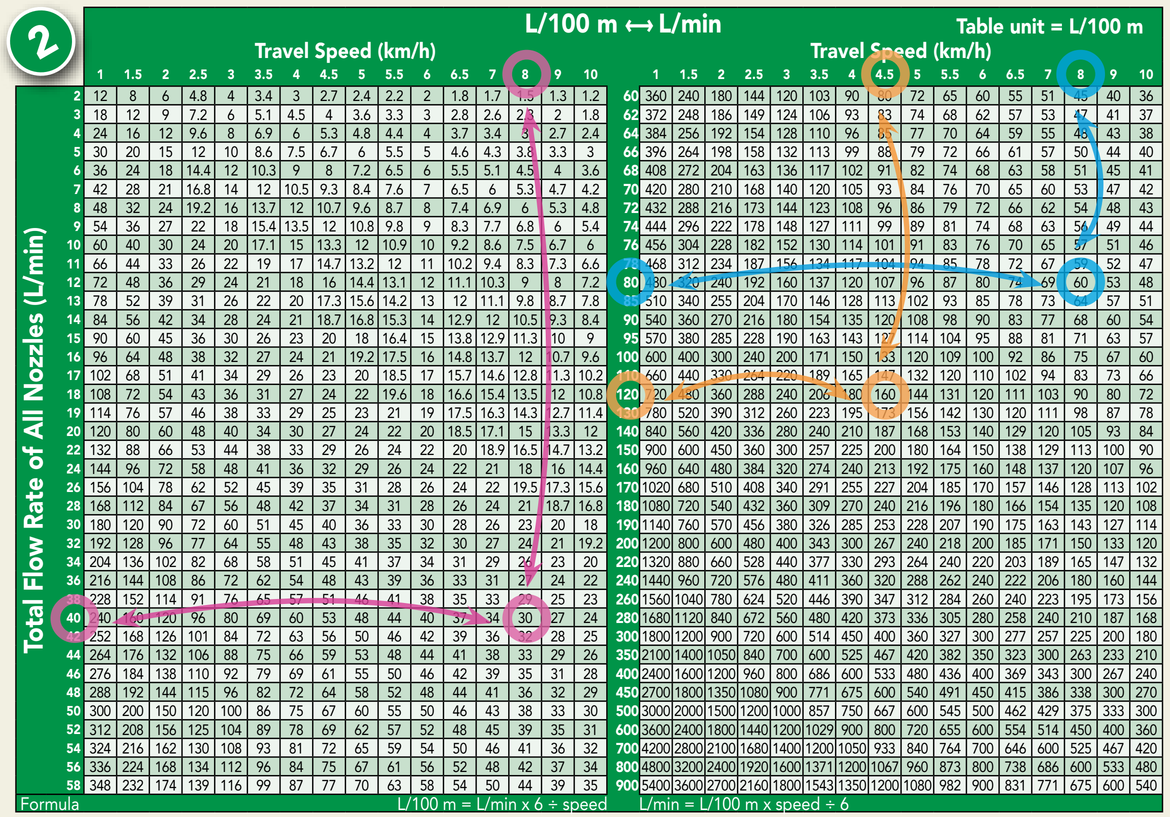


Figure 91

ATR HOLLOW CONE FLOWRATE CHART

3

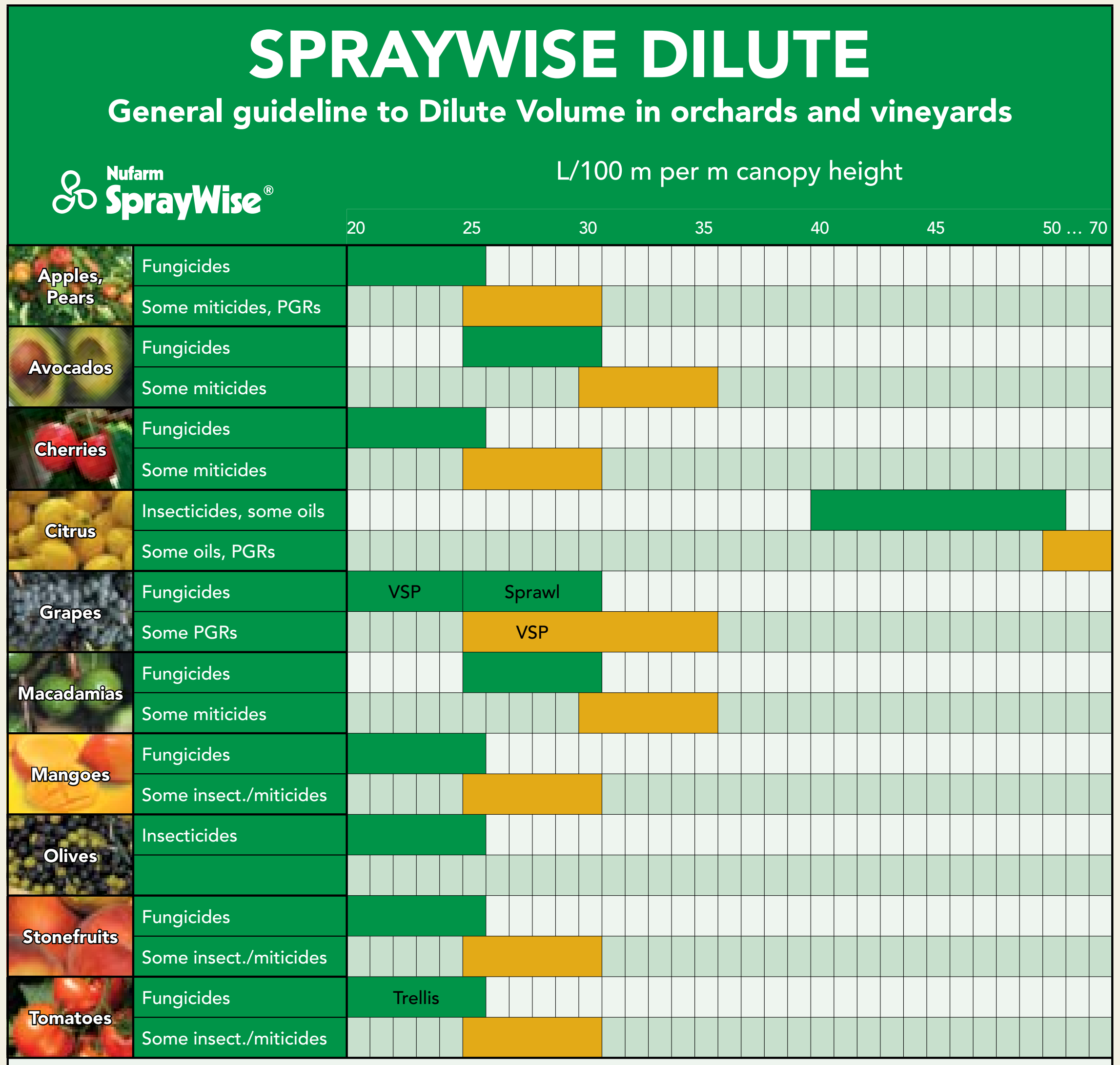
PRESSURE (BAR)	White	Lilac	Brown	Yellow	Orange	Red	Grey	Green	Black	Blue
	L/MIN									
5	0.27	0.36	0.48	0.73	0.99	1.38	1.5	1.78	2	2.45
6	0.29	0.39	0.52	0.8	1.08	1.51	1.63	1.94	2.18	2.67
7	0.32	0.42	0.56	0.86	1.17	1.62	1.76	2.09	2.35	2.87
8	0.34	0.45	0.6	0.92	1.24	1.73	1.87	2.22	2.5	3.06
9	0.36	0.48	0.64	0.97	1.32	1.83	1.98	2.35	2.64	3.24
10	0.38	0.5	0.67	1.03	1.39	1.92	2.08	2.47	2.78	3.4
11	0.39	0.52	0.7	1.07	1.45	2.01	2.17	2.58	2.9	3.56
12	0.41	0.55	0.73	1.12	1.51	2.09	2.26	2.69	3.03	3.71
13	0.43	0.57	0.76	1.17	1.57	2.17	2.35	2.79	3.14	3.85
14	0.44	0.59	0.79	1.21	1.63	2.25	2.43	2.89	3.26	3.99
15	0.46	0.61	0.81	1.25	1.69	2.33	2.51	2.99	3.36	4.12
16	0.47	0.63	0.84	1.29	1.74	2.4	2.59	3.08	3.47	4.25
17	0.48	0.64	0.86	1.33	1.79	2.47	2.67	3.17	3.57	4.37
18	0.5	0.66	0.89	1.37	1.84	2.54	2.74	3.25	3.67	4.49
19	0.51	0.68	0.91	1.4	1.89	2.6	2.81	3.34	3.76	4.61
20	0.52	0.7	0.93	1.44	1.94	2.67	2.88	3.42	3.85	4.72

ALBUZ® Equivalent*	TVI	Purple 80–0050	Pink 80–0075	Orange 80–01	Green 80–015	Yellow 80–02	Lilac 80–025	Blue 80–03	Blue 80–03	Red 80–03	Red 80–03
TeeJet® Equivalent*	TX	TX-VK3	TX-VK4	TX-VK6	TX-VK8	TX-VK12	TX-VK18	TX-VK18	TX-VK18	TX-VK26	TX-VK26
	TXB80	TXB-050VK	TXB-067VK	TXB-01VK	TXB-015VK	TXB-02VK	TXB-03VK	TXB-03VK	TXB-03VK	TXB-04VK	TXB-04VK

Note: Colours in table represent actual nozzle colour. ALBUZ® TVI and TXB80 TeeJet® nozzle range are ISO colour coded. Nozzles with the same colour have the same output. The ALBUZ® ATR and TeeJet® TX range are NOT ISO colour coded. Their nozzle colour is not related to a specific output.

Figure 92

SPRAYWISE DILUTE



■ = indicates Dilute Volume, sprayed to the point of run-off

■ = indicates light flood Volume, above the point of run-off (some miticides, insecticides and PGRs may benefit)

Example: A 3 m high apple canopy should need a dilute rate between 60 - 75 L /100 m (3 x 20 or 3 x 25). As a sanity check, at a row spacing of 4 m that converts to 1500 - 1900 L/ha (see table next page). If not sure which way to go, as a sophisticated guess, the middle should be close, e.g. 70 L/100 m.

IMPORTANT:

- Volumes are given for full canopy
- Volumes may vary according to canopy type, e.g. VSP vs Sprawl, shape and density. Use the lower end of the spectrum for easier to cover targets, e.g in grapes use 20–25 for VSP and 25–30 for Sprawl
- Height considers canopy height only - excluding the trunk
- Guidelines assume that the sprayer is set up to cover the canopy height. In early season grapevine applications the minimum sprayer width becomes the canopy height! For example, a Croplands Quantum Mist™ head covers 1 m. It can not be reduced to cover 10 cm shoots only. Therefore the Dilute Volume has to operate on the minimum width the equipment can produce

RATE FOR EARLY SEASON APPLICATIONS IN DECIDUOUS TREE/VINE CROPS (in L/100 m per m Canopy Height)

Budburst	1st Spray BB+10 days	2nd Spray BB+20 days	3rd Spray BB+30 days
14L (70 % of 20 L)	16L (80% of 20 L)	18L (90% of 20 L)	Full rate

Figure 93

SELECTING NOZZLES FOR TREE AND VINE SPRAYING

HEADING

1

L/ha ⟷ L/100 m — Table unit = L/100 m

Row Spacing (m)

L/ha	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
100	1.6	1.8	2	2.1	2.4	2.5	2.7	2.8	2.9	3	3.1	3.2	3.3	3.5	3.6	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10
150	2.4	2.7	3	3.1	3.6	3.8	4	4.2	4.4	4.5	4.7	4.8	5	5.3	5.4	6	6.8	7.5	8.3	9	9.8	10.5	11.3	12	12.8	13.5	15
200	3.2	3.6	4	4.2	4.8	5	5.4	5.6	5.8	6	6.2	6.4	6.7	7	7.2	8	9	10	11	12	13	14	15	16	17	18	20
250	4	4.5	5	5.2	6	6.3	6.7	7	7.3	7.5	7.8	8	8.3	8.8	9.0	10	11.3	12.5	13.8	15	16.3	17.5	18.8	20	21	23	25
300	4.8	5.4	6	6.3	7.1	7.5	8.1	8.4	8.7	9	9.3	9.6	10	10.5	10.8	12	13.5	15	16.5	18	19.5	21	23	24	26	27	30
350	5.6	6.3	7	7.3	8.3	8.8	9.4	9.8	10.2	10.5	10.9	11.2	11.7	12.3	12.6	14	15.8	17.5	19.3	21	23	25	26	28	30	32	35
400	6.4	7.2	8	8.3	9.5	10	10.8	11.2	11.6	12	12.4	12.8	13.3	14	14.4	16	18	20	22	24	26	28	30	32	34	36	40
450	7.2	8.1	9	9.4	11	11.3	12.1	12.6	13.1	13.5	14	14.4	15	15.8	16.2	18	20	23	25	27	29	32	34	36	38	41	45
500	8	9	10	10	12	12.5	13.5	14	14.5	15	15.5	16	16.7	17.5	18	20	23	25	28	30	33	35	38	40	43	45	50
600	9.6	10.8	12	13	14	15	16.2	16.8	17.4	18	18.6	19.2	20	21	22	24	27	30	33	36	39	42	45	48	51	54	60
700	11.2	12.6	14	15	17	17.5	18.9	19.6	20	21	22	22	23	25	25	28	32	35	39	42	46	49	53	56	60	63	70
750	12	13.5	15	16	18	18.8	20	21	22	23	23	24	25	26	27	30	34	38	41	45	49	53	56	60	64	68	75
800	12.8	14.4	16	17	19	20	22	22	23	24	25	26	27	28	29	32	36	40	44	48	52	56	60	64	68	72	80
900	14.4	16.2	18	19	21	23	24	25	26	27	28	29	30	32	32	36	41	45	50	54	59	63	68	72	77	81	90
1000	16	18	20	21	24	25	27	28	29	30	31	32	33	35	36	40	45	50	55	60	65	70	75	80	85	90	100
1100	17.6	19.8	22	23	26	28	30	31	32	33	34	35	37	39	40	44	50	55	61	66	72	77	83	88	94	99	110
1200	19.2	22	24	25	29	30	32	34	35	36	37	38	40	42	43	48	54	60	66	72	78	84	90	96	102	108	120
1300	21	23	26	27	31	33	35	36	38	39	40	42	43	46	47	52	59	65	72	78	85	91	98	104	111	117	130
1400	22	25	28	29	33	35	38	39	41	42	43	45	47	49	50	56	63	70	77	84	91	98	105	112	119	126	140
1500	24	27	30	31	36	38	40	42	44	45	47	48	50	53	54	60	68	75	83	90	98	105	113	120	128	135	150
1600	26	29	32	33	38	40	43	45	46	48	50	51	53	56	58	64	72	80	88	96	104	112	120	128	136	144	160
1700	27	31	34	35	40	43	46	48	49	51	53	54	57	60	61	68	77	85	94	102	111	119	128	136	145	153	170
1800	29	32	36	38	43	45	49	50	52	54	56	58	60	63	65	72	81	90	99	108	117	126	135	144	153	162	180
1900	30	34	38	40	45	48	51	53	55	57	59	61	63	67	68	76	86	95	105	114	124	133	143	152	162	171	190
2000	32	36	40	42	48	50	54	56	58	60	62	64	67	70	72	80	90	100	110	120	130	140	150	160	170	180	200
2500	40	45	50	52	60	63	67	70	73	75	78	80	83	88	90	100	113	125	138	150	163	175	188	200	213	225	250
3000	48	54	60	63	71	75	81	84	87	90	93	96	100	105	108	120	135	150	165	180	195	210	225	240	255	270	300
4000	64	72	80	83	95	100	108	112	116	120	124	128	133	140	144	160	180	200	220	240	260	280	300	320	340	360	400
5000	80	90	100	104	119	125	135	140	145	150	155	160	167	175	180	200	225	250	275	300	325	350	375	400	425	450	500
6000	96	108	120	125	143	150	162	168	174	180	186	192	200	210	216	240	270	300	330	360	390	420	450	480	510	540	600
7000	112	126	140	146	167	175	189	196	203	210	217	224	233	245	252	280	315	350	385	420	455	490	525	560	595	630	700
8000	128	144	160	167	190	200	216	224	232	240	248	256	266	280	288	320	360	400	440	480	520	560	600	640	680	720	800
9000	144	162	180	188	214	225	243	252	261	270	279	288	300	315	324	360	405	450	495	540	585	630	675	720	765	810	900
10000	160	180	200	208	238	250	270	280	290	300	310	320	333	350	360	400	450	500	550	600	650	700	750	800	850	900	1000
Conversion Factor	62.5	55.5	50	47.6	41.7	40	37.0	35.7	34.5	33.3	32.3	31.3	30.3	28.6	27.8	25	22.2	20	18.2	16.7	15.4	14.3	13.3	12.5	11.8	11.1	10

Formula: L/100 m = L/ha ÷ 100 x row spacing (m) — L/ha = L/100 m x 100 ÷ row spacing (m)

Figure 94

HEADING

2

L/100 m ⟷ L/min

Total Flow Rate of All Nozzles (L/min); Travel Speed (km/h)

L/min	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	8	9	10	L/min	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	8	9	10
2	12	8	6	4.8	4	3.4	3	2.7	2.4	2.2	2	1.8	1.7	1.5	1.3	1.2	60	360	240	180	144	120	103	90	80	72	65	60	55	51	45	40	36
3	18	12	9	7.2	6	5.1	4.5	4	3.6	3.3	3	2.8	2.6	2.3	2	1.8	62	372	248	186	149	124	106	93	83	74	68	62	57	53	47	41	37
4	24	16	12	9.6	8	6.9	6	5.3	4.8	4.4	4	3.7	3.4	3	2.7	2.4	64	384	256	192	154	128	110	96	85	77	70	64	59	55	48	43	38
5	30	20	15	12	10	8.6	7.5	6.7	6	5.5	5	4.6	4.3	3.8	3.3	3	66	396	264	198	158	132	113	99	88	79	72	66	61	57	50	44	40
6	36	24	18	14.4	12	10.3	9	8	7.2	6.5	6	5.5	5.1	4.5	4	3.6	68	408	272	204	163	136	117	102	91	82	74	68	63	58	51	45	41
7	42	28	21	16.8	14	12	10.5	9.3	8.4	7.6	7	6.5	6	5.3	4.7	4.2	70	420	280	210	168	140	120	105	93	84	76	70	65	60	53	47	42
8	48	32	24	19.2	16	13.7	12	10.7	9.6	8.7	8	7.4	6.9	6	5.3	4.8	72	432	288	216	173	144	123	108	96	86	79	72	66	62	54	48	43
9	54	36	27	22	18	15.4	13.5	12	10.8	9.8	9	8.3	7.7	6.8	6	5.4	74	444	296	222	178	148	127	111	99	89	81	74	68	63	56	49	44
10	60	40	30	24	20	17.1	15	13.3	12	10.9	10	9.2	8.6	7.5	6.7	6	76	456	304	228	182	152	130	114	101	91	83	76	70	65	57	51	46
11	66	44	33	26	22	19	17	14.7	13.2	12	11	10.2	9.4	8.3	7.3	6.6	78	468	312	234	187	156	134	117	104	94	85	78	72	67	59	52	47
12	72	48	36	29	24	21	18	16	14.4	13.1	12	11.1	10.3	9	8	7.2	80	480	320	240	192	160	137	120	107	96	87	80	74	69	60	53	48
13	78	52	39	31	26	22	20	17.3	15.6	14.2	13	12	11.1	9.8	8.7	7.8	85	510	340	255	204	170	146	128	113	102	93	85	78	73	64	57	51
14	84	56	42	34	28	24	21	18.7	16.8	15.3	14	12.9	12	10.5	9.3	8.4	90	540	360	270	216	180	154	135	120	108	98	90	83	77	68	60	54
15	90	60	45	36	30	26	23	20	18	16.4	15	13.8	12.9	11.3	10	9	95	570	380	285	228	190	163	143	127	114	104	95	88	81	71	63	57
16	96	64	48	38	32	27	24	21	19.2	17.5	16	14.8	13.7	12	10.7	9.6	100	600	400	300	240	200	171	150	133	120	109	100	92	86	75	67	60
17	102	68	51	41	34	29	26	23	20	18.5	17	15.7	14.6	12.8	11.3	10.2	110	660	440	330	264	220	189	165	147	132	120	110	102	94	83	73	66
18	108	72	54	43	36	31	27	24	22	19.6	18	16.6	15.4	13.5	12	10.8	120	720	480	360	288	240	206	180	160	144	131	120	111	103	90	80	72
19	114	76	57	46	38	33	29	25	23	21	19	17.5	16.3	14.3	12.7	11.4	130	780	520	390	312	260	223	195	173	156	142	130	120	111	98	87	78
20	120	80	60	48	40	34	30	27	24	22	20	18.5	17.1	15	13.3	12	140	840	560	420	336	280	240	210	187	168	153	140	129	120	105	93	84
22	132	88	66	53	44	38	33	29	26	24	22	20	18.9	16.5	14.7	13.2	150	900	600	450	360	300	257	225	200	180	164	150	138	129	113	100	90
24	144	96	72	58	48	41	36	32	29	26	24	22	21	18	16	14.4	160	960	640	480	384	320	274	240	213	192	175	160	148	137	120	107	96
26	156	104	78	62	52	45	39	35	31	28	26	24	22	19.5	17.3	15.6	170	1020	680	510	408	340	291	255	227	204	185	170	157	146	128	113	102
28	168	112	84	67	56	48	42	37	34	31	28	26	24	21	18.7	16.8	180	1080	720	540	432	360	309	270	240	216	196	180	166	154	135	120	108
30	180	120	90	72	60	51	45	40	36	33	30	28	26	23	20	18	190	1140	760	570	456	380	326	285	253	228	207	190	175	163	143	127	114
32	192	128	96	77	64	55	48	43	38	35	32	30	27	24	21	19.2	200	1200	800	600	480	400	343	300	267	240	218	200	185	171	150	133	120
34	204	136	102	82	68	58	51	45	41	37	34	31	29	26	23	20	220	1320	880	660	528	440	377	330	293	264	240	220	203	189	165	147	132
36	216	144	108	86	72	62	54	48	43	39	36	33	31	27	24	22	240	1440	960	720	576	480	411	360	320	288	262	240	222	206	180	160	144
38	228	152	114	91	76	65	57	51	46	41	38	35	33	29	25	23	260	1560	1040	780	624	520	446	390	347	312	284	260	240	223	195	173	156
40	240	160	120	96	80	69	60	53	48	44	40	37	34	30	27	24	280	1680	1120	840	672	560	480	420	373	336	305	280	258	240	210	187	168
42	252	168	126	101	84	72	63	56	50	46	42	39	36	32	28	25	300	1800	1200	900	720	600	514	450	400	360	327	300	277	257	225	200	180
44	264	176	132	106	88	75	66	59	53	48	44	41	38	33	29	26	350	2100	1400	1050	840	700	600	525	467	420	382	350	323	300	263	233	210
46	276	184	138	110	92	79	69	61	55	50	46	42	39	35	31	28	400	2400	1600	1200	960	800	686	600	533	480	436	400	369	343	300	267	240
48	288	192	144	115	96	82	72	64	58	52	48	44	41	36	32	29	450	2700	1800	1350	1080	900	771	675	600	540	491	450	415	386	338	300	270
50	300	200	150	120	100	86	75	67	60	55	50	46	43	38	33	30	500	3000	2000	1500	1200	1000	857	750	667	600	545	500	462	429	375	333	300
52	312	208	156	125	104	89	78	69	62	57	52	48	45	39	35	31	600	3600	2400	1800	1440	1200	1029	900	800	720	655	600	554	514	450	400	360
54	324	216	162	130	108	93	81	72	65	59	54	50	46	41	36	32	700	4200	2800	2100	1680	1400	1200	1050	933	840	764	700	646	600	525	467	420
56	336	224	168	134	112	96	84	75	67	61	56	52	48	42	37	34	800	4800	3200	2400	1920	1600	1371	1200	1067	960	873	800	738	686	600	533	480
58	348	232	174	139	116	99	87	77	70	63	58	54	50	44	39	35	900	5400	3600	2700	2160	1800	1543	1350	1200	1080	982	900	831	771	675	600	540

Formula: L/100 m = L/min x 6 ÷ speed — L/min = L/100 m x speed ÷ 6

Figure 94

SET-UP

CHAPTER SUMMARY

- Use markers such as clays, dyes, or water sensitive paper for assessment
- Step 1 – Plan
  - Work out theoretical requirements
    - Dilute Volume
    - Does the Concentrate X-Factor apply?
    - Speed
    - Pressure
    - Nozzles
    - Volume or markers needed
- Step 2 – Execute
  - Adjust sprayer to target canopy
  - Check inputs into rate controller
  - Spray a row from both sides
- Step 3 – Evaluate
- Step 4 – Adjust

STEP 1: THEORETICAL CONSIDERATION (PLAN)

- Determine the Dilute Volume using the SprayWise Dilute chart on page 27 or 55.
- Decide whether to spray with a Dilute or Concentrate Volume – noting that it is unlikely that for you to be able to test both volumes using a single set of nozzles. As a general rule, to double or halve a water volume – pressure needs to change 4 fold.
- Select a travel speed that is comfortable noting that sufficient time is required for the equipment to penetrate into the canopy
- According to the speed and volume, select a suitable nozzle size and type, ensuring the selected nozzle allows for pressure adjustments
- As Tank-fill Volume is increased, the cost of using dyes and markers such as Surround increases. Budget to allow for 4-6 50-60m runs of both sides of the canopy. Remember the tank will need a base volume to operate and that some volume will need to remain to clear the lines is using dyes and markers. If possible, spray using a single side of the sprayer to save water.
- Decide on which marker to use. Using Surround with a 1.25kg/100L rate is recommended. If using dye, operate with a rate of 500ml/100L. As a minimum you'd generally need 2 litres of dye, 1 bag of Surround or 1 pack of water-sensitive paper to assess a machine. Multiply this if assessing multiple machines and apply the X-factor when using a concentrate spray.

AN EXAMPLE OF PLANNING

- A 4m high apple canopy with 5m row spacing requires 80L/100m (1600L/ha) at full canopy
- Based on this Dilute Volume a grower chooses to spray at 4X (400L/ha at 5m row spacing)
- Good coverage can be achieved using a Quantum Mist sprayer at 10km/hr
- When choosing a nozzle capable of outputting 0.7L/min and considering an effective pressure range of 5 to 20 bar it would be wise to choose a nozzle that outputs 0.7L/min at 12 bar (TXB8001) as opposed to a nozzle that outputs this at 6 bar (TXB8015) – this ensures that there is a degree of flexibility if adjustments are required
- Given a Dilute Volume rate of 80L/100m and a desire to evaluate over 300m (+50m) tank volume must be a minimum of 500L. This includes 60L for clearing lines and the 200L that is required to meet the minimum operating volume.
- With a minimum of 500L a grower must budget on utilising 6.25kg of Surround (1.25kg/100L)
- If the grower chooses to spray a 4X concentrate they must budget 25kg (2 bags) of Surround. 4X the rate of Surround is required as the Tank-fill Volume is now required to cover 4 times more area than the Dilute example. When concentrate spraying it is better to use as little water as possible.

SET-UP

STEP 2: INITIAL SET-UP (EXECUTE)

- Fit the desired nozzles to the sprayer
- Fill the tank with the desired water volume
- Ensure the automatic rate controller has the right inputs - L/100m or L/ha, row width, activated arms
- If using clay or dye, turn agitation on and add product
- Drive the sprayer into the orchard and park in the centre of the row
- Aiming at the target canopy, adjust the spray width by changing fan angle, volute direction of nozzle directions
- If required, place water sensitive paper in the canopy
- Drive the sprayer out of the block and prime the lines for 30 seconds
- Spray a short section (25-50m at the right speed is enough) from both sides
- If possible, observe the application from a distance when spraying high targets

STEP 3: ASSESSMENT (EVALUATE)

When using Surround it is better to wait 20 minutes after application for clay to dry as opposed to water-sensitive paper which is better assessed within minutes of application. Basic requirements for coverage are:

- Whole canopy coverage (unless band spraying)
- At least 70% of the surface should be covered sufficiently
- In any given area (tree top, inner canopy, fruit) at least 50% of the area should be sufficiently covered

If the coverage appears poor, the set-up requires adjusting. Identify the most likely causes for inadequate results and systematically address critical factors.

STEP 4: ADJUST

In tree and vine applications;

It is possible to overcome **bad coverage on tree tops** by:

- Directing higher water volumes to tree tops (i.e. changing nozzle output to 60% top, 40% bottom)
- Using a flood volume for the top
- Using coarser droplets for the top by changing nozzles
- Changing angles of air volutes or fans

N.B When spraying tree tops higher than 5 metres using an Air Blast sprayer, gun nozzles may need to be used.

It is possible to overcome **bad coverage in the inner canopy** by:

- Adjusting air speed or air volume. Too much air results in tiling of leaves and too little air results in insufficient penetration. Air volume can be adjusted by changing fan gears, covering intakes or - if using a Quantum Mist – adjusting RPM.
- Reduce speed – giving your sprayer more time to penetrate
- As a last resort, increase water volume

It is possible to overcome **banding** by adjusting fans, volute or nozzles, changing angles, or adjusting distance to canopy.

It is possible to overcome **bad fruit coverage** by adding adjuvants to optimise deposition and coverage.

Poor coverage on the back of fruits and leaves can be remedied by adding adjuvants to modify droplet behavior.

In vegetables applications; It is possible to overcome **bad coverage on the backs of erect crops** (i.e onions) by changing to flat fan nozzles.

It is possible to overcome **bad coverage on hard to wet crops** (i.e onions and Brassicas) by decreasing water volume and replacing it with Du-Wett or Designer (page 38) or increase deposition with adjuvants.

Little coverage on the bottom of dense crops (i.e potatoes) can be improved by using a combination of FINE and COARSE droplets or only COARSE droplets, using Du-Wett or Designer (page 38) or utilising air assist.

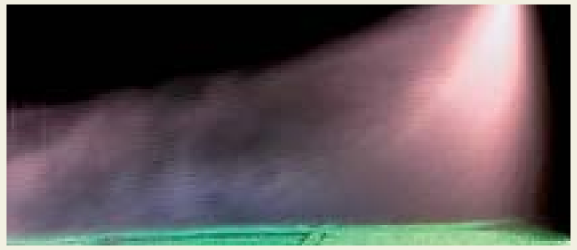
NOZZLE CHOICE AND SET-UP NOTES

CHAPTER SUMMARY

- Choose the nozzle that produces the coarsest spray quality without compromising efficacy
- Use the appropriate pressure for a specific nozzle type (conventional nozzles 1.5-3 bar, pre-orifice nozzles 2-4 bar, low-pressure air induction nozzles 3-5 bar, high-pressure air induction nozzles 4-8 bar)
- Avoid spraying in situations conducive to temperature inversions
- Spray only when wind speed is in the range of 3-20 km/h (15 km/h maximum for 2,4-D products)
- Avoid non-ionic surfactants where possible – use drift-reducing adjuvants instead (e.g. LI 700®)
- Avoid spraying with boom heights greater than recommended (50 cm for 110˚ flat fan nozzles and 75 cm for 85˚ nozzles)
- If possible use machinery that directs the spray into the crop (e.g. Croplands Quantum Mist™) instead of machinery that directs the spray up into the air (e.g. Cropliner without valute)
- 6 row hedger

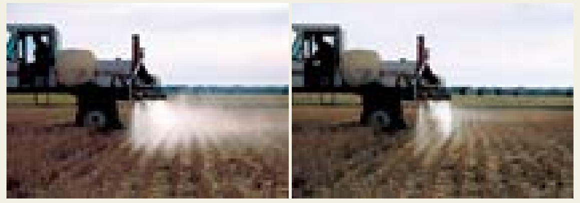
HEADING

Physical droplet spray drift



Nozzle type: Standard flat fan; Nozzle size: 03; Wind speed: 2m/s; Height: 800 mm; Pressure: 3 bar

Crop Damage from Spray Drift
(Note the protective effect of the bush vegetation on left)



FINE to MEDIUM spray quality with XR TeeJet® nozzles (above left) compared to VERY COARSE spray quality with agrotop TurboDrop® nozzles (above right)

Figure 96

SPRAY DRIFT

Spray drift is a major concern in most agricultural areas today with sensitive crops and orchards growing adjacent to the spray target area, there is the possibility of off-target damage. All pesticides, herbicides, insecticides, PGR's and fungicides have the potential to drift and consequently cause economic damage. Typical examples of the deleterious effects of drift are crop damage resulting in yield loss; trade embargos caused by food chain contamination or stock and human health issues.

Care needsto be taken when when an agricultural chemical is used for the control of pests and weeds to ensure the product and the way it is applied does not pose a risk to neighbouring properties.
One of the most visual risks to sensitive crops or neighbouring properties is herbicide drift.

There are two types of herbicide drift: physical spray drift, which can occur with any herbicide, and vapour drift, which is influenced by herbicide's volatility. Physical spray drift is the more common form of off-target movement of spray droplets.

PHYSICAL OR DROPLET DRIFT

Physical spray drift is the movement of spray droplets away from the target onto neighbouring crops or paddocks. Physical spray drift is strongly influenced by application set-up and environmental conditions. The major factor for drift potential is droplet size. Using fine droplets, setting the boom too high, travelling too fast, spraying in strong winds or upwind of sensitive crops, or spraying in weather conditions that favour droplet survival, such as high humidity, are just some of the causes of physical spray drift.

VAPOUR DRIFT

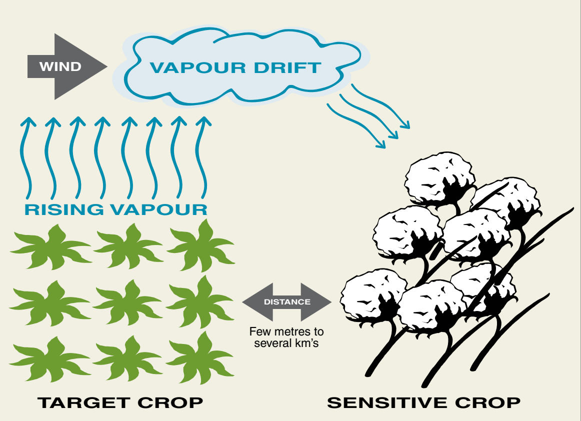


Figure 97

VAPOUR DRIFT

Vapour drift is the movement of an active as a vapour, away from the target area. A major factor influencing vapour drift is the volatility of the pesticide used.

Few herbicides have the potential to cause vapour drift (e.g. short-chained, highly volatile phenoxies such as Nufarm Estercide® 800 or pendimethalin under vines). Vapour drift can arise directly from the spray solution or evaporate from sprayed surfaces, such as plant leaves (this occurs in the majority of instances) and soil surface (minority). Vapour drift has the potential - in the right conditions - to move unpredictably over tens of kilometres and still affect sensitive crops, such as cotton, grapevines and other horticultural crops.

In Australia, severe legislative use restrictions on short chain phenoxies have greatly reduced the risk of vapour drift.

The easiest way to avoid vapour drift, and the one over which the applicator has most control, is the selection of a non-volatile 2,4-D formulation (Figure 98) e.g. the selection of Nufarm Amicide® Advance.

SPRAY DRIFT LABEL RESTRAINTS

In March 2010 the APVMA began implementing new label requirements for drift management which are still under review. 2,4-D chemistry related labels change first. Gradually all registered labels will follow, but this process will take several years. Under the new requirements, all product labels will have to state a single minimum spray quality. For example, the 2,4-D label statement has changed to "DO NOT apply with spray droplets smaller than COARSE."

HEADING

Estercide®800 800 g/L 2,4-D present as the ethyl ester	High Volatility
Broadside™ 280 g/L MCPA present as the iso-octyl ester 140 g/L bromoxynil present as the octanoate ester 40 g/L dicamba present as the acid	Low Volatility
Bromicide® MA 200 g/L bromoxynil present as the n-octanoyl ester 200 g/L MCPA present as the ethyl hexyl ester	Low Volatility
Comet® 400 400 g/L fluroxypyr present as the methlyheptyl ester	Low Volatility
Conqueror® 300 g/L triclopyr present as the butoxyethyl ester 100 g/L picloram present as the hexyloxypropylamine salt	Low Volatility
Estercide Xtra 680 680 g/L 2,4-D present as the ethyl hexyl ester	Low Volatility
Invader® 600 600 g/L triclopyr present as the butoxyethyl ester	Low Volatility
LVE Agritone® 570 g/L MCPA present as the iso-octyl ester	Low Volatility
Bromicide 200 200 g/L bromoxynil present as the n-octanoyl ester	Low Volatility #
Agritone® 750 750 g/L MCPA present as the dimethylamine salt	Non-Volatile
Amicide® Advance 700 700 g/L 2,4-D present as the monomethylamine and dimethylamine salts	Non-Volatile
Archer® 300 g/L clopyralid present as the triisopropanolamine salt	Non-Volatile
Buttress® 500 g/L 2,4-DB present as the dimethylamine salt	Non-Volatile
Kamba® 500 500 g/L dicamba present as the dimethylamine salt	Non-Volatile
Kamba M 340 g/L dicamba present as the dimethylamine salt 80 g/L dicamba present as the dimethylamine salt	Non-Volatile
Nuquat® 250 250 g/L paraquat present as paraquat dichloride	Non-Volatile
Revolver® 135 g/L paraquat present as paraquat dichloride 115 g/L diquat present as diquat dibromide	Non-Volatile
weedmaster® DST 450 g/L glyphosate present as the isopropylamine salt	Non-Volatile
weedmaster® ARGO® 540 g/L glyphosate present as the potassium and isopropylamine salts	Non-Volatile
Striker® 240 g/L oxyfluorfen	Non-Volatile
Trooper® 242 420 g/L MCPA present as the potassium salt 26 g/L picloram present as the potassium salt	Non-Volatile

Figure 98 # Phenoxy volatility safe to use near sensitive crops

Spray quality statement also appeared on many newer horticultural product labels, " DO NOT spray with a spray quality smaller than MEDIUM".
Yet, most airblast sprayers produce a VERY FINE to FINE spray quality. The APVMA has recognized this dilemma and issued a permit (PER 80651) to exempt airblast equipment. " Except when applying with vineyard airblast equipment DO NOT spray with a spray quality smaller than MEDIUM". This direction applies currently to all new or updated labels.

DRIFT

EXAMPLE NEW APVMA LABEL RESTRAINTS

DO NOT apply if there are sensitive crops, gardens, landscaping vegetation, protected native vegetation or protected animal habitat downwind from the application area and within the mandatory no-spray zones shown in the table below.

FOR AERIAL APPLICATION		
Wind Speed Range at Time of Application	Downwind Mandatory No-Spray Zone	
	Fixed Wing	Helicopter
from 3 to 8 kilometres per hour	XXX metres	MMM metres
from 8 to 14 kilometres per hour	YYYmetres	PPP metres
from 14 to 20 kilometres per hour	ZZZ metres	QQQ metres
FOR GROUND APPLICATION		
from 3 to 20 kilometres per hour	WWW metres	

Figure 99

HORIZONTAL AIRBORNE SPRAY PROFILES MEASURED IN WIND TUNNEL TESTS

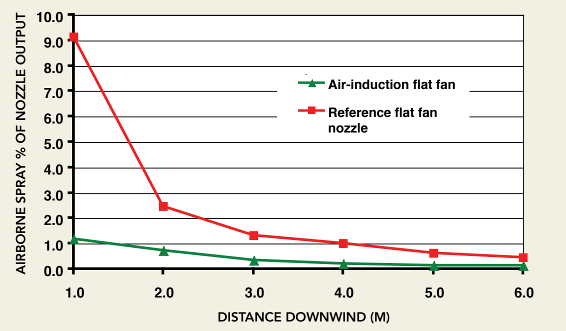


Figure 100 Source: Paul Miller, Silsoe

NOZZLE PRESSURE AFFECTS DRIFT

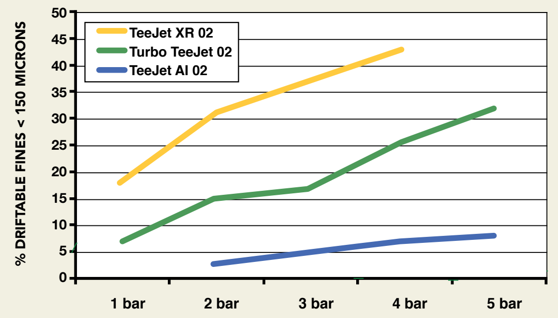


Figure 101 Source: TeeJet® data

According to the spray quality specified by the manufacturer and the risk specific chemistry poses to the safety of surrounding crops, the environment and human health the APVMA imposes mandatory downwind no-spray zones. These buffers may range from several meters to several hundred meters.

Currently the risk assessment for no-spray areas is carried out for four scenarios:

- **Human Health**
  DO NOT apply if there are people, structures that people occupy or parks and recreation areas within 'xxx' meters downwind from the application area.
- **Environment - Aquatic**
  DO NOT apply if there are aquatic and wetland areas including aquacultural ponds, surface streams and rivers within 'yyy' meters downwind from the application area.
- **Environment - Terrestrial**
  DO NOT apply if there are sensitive crops, gardens, landscaping vegetation, protected native vegetation or protected animal habitat within 'zzz' meters downwind from the application area.
- **International Livestock Trade**
  DO NOT apply if there are livestock, pasture or any land that is producing feed for livestock within 'uuu' meters downwind from the application area.

On some labels these buffers have already been implemented. On the vast majority they will be implemented over the next few years. Read the label.

As well as these restraints additional state legislation may apply. Some states have installed extensive exclusion areas for 2,4-D formulations around horticultural crops. All of these measures severely affect operational flexibility for growers so it is more important than ever the agriculture demonstrates responsible usage of chemicals, to reduce the need for more severe restrictions.

DRIFT REDUCTION

Machinery type, set-up and droplet size are the most important factors to minimise physical drift levels. They are also the factors over which the applicator has the most control. Below is a list of critical factors the applicator should always manage to minimise drift risk.

DRIFT

SPRAY DIRECTION (TREE AND VINE CROPS)

If possible use machinery that directs the spray into the crop (e.g. Croplands Quantum Mist™) instead of machinery that directs the spray up into the air (e.g. Cropliner without valute).

NOZZLE SELECTION

Nozzle selection is critical to control droplet size. Choose the coarsest spray quality without compromising efficacy. In general, nozzles that produce a COARSE spray quality will provide sufficient efficacy in most herbicide applications.

PRESSURE FOR BOOM-NOZZLES

Spray quality is not only governed by the type of nozzle but also by the pressure used. Use the appropriate pressure for specific nozzle types to ensure optimum performance.

Conventional nozzles 1.5-3 bar, pre-orifice nozzles 2-4 bar, low-pressure air induction nozzles 3-5 bar, high-pressure air-induction nozzles 4-8 bar, hollow cone nozzles 5-20 bar.

SPRAY TIP HEIGHT FOR GROUND RIGS

The spray tip height for 110° flat fan nozzles should not exceed 50 cm for a 50 cm nozzle spacing set-up and 75 cm in height for 85° spray tips. The finer the spray quality the more critical it is to avoid excessive boom height.

With a COARSE or coarser spray quality, maximum height requirements can be relaxed. Many applicators running equipment with a very wide boom span raise the boom height to reduce soil ditching of the boom tips. In those situations, selection of a COARSE spray quality is paramount.

ADJUVANTS

Non-ionic surfactants should be avoided if possible because they generally increase the amount of driftable fines (see page 72). Instead, drift-reducing adjuvants such as Nufarm LI 700®, Nufarm Activator® or Nufarm Banjo®.

WIND VELOCITY

Only carry out applications when wind speed is in the range of 3-20 km/h (15 km/h maximum for 2,4-D products). Wind speed becomes more important with a finer spray quality. Large droplets from coarser spray qualities are less affected because they drop to the ground easily. To reduce drift the droplet size is more important than wind speed.

TEMPERATURE/RELATIVE HUMIDITY

Never spray in low-level temperature inversions (see page 65). Very low Delta T levels may prolong the lifespan of drifting droplets and should be avoided (see page 64).

WEATHER

CHAPTER SUMMARY

- The majority of the time the weather is only marginal or unsuitable for spraying

To gain more flexibility from the weather, spray with the coarsest spray quality possible without compromising efficacy

- Measure and record local conditions at the time of application (e.g. use WindMate™, tractor-mounted weather station)
- DO NOT spray in inversion conditions
- DO NOT spray when the wind is blowing towards susceptible crops
- Spray when Delta T is between 2 and 8 (10 with a COARSE spray quality)
- The addition of adjuvants providing humectancy (e.g. Nufarm LI 700) will be beneficial under high Delta T conditions
- Avoid spraying in temperatures above 30°C
- DO NOT spray in too calm or too gusty winds. Spray when wind is steady and between 3 and 20 km/h (15 km/h max. for 2,4-D products)
- Be aware of local paddock conditions and likely changes before, during and after the spray application

GENERAL

Weather plays a major role in the application process and more often than not is only marginal for spraying. Depending on the location an estimated 15-25% of all days provide favourable spraying conditions.

This chapter deals with the main weather factors that affect application, all of which are linked. Critical to understanding drift is the section about inversions, especially in combination with katabatic winds. It is equally important to understand local conditions, which can vary significantly from the broader-scale information provided by the Bureau of Meteorology.

WIND

The main effect of wind on application is its potential to displace spray droplets or vapour far away from the intended target, therefore causing chemical loss or drift damage on susceptible crops.

Wind speed is generally lowest in the morning, increasing to a maximum between late morning and mid-afternoon, and dropping off again towards sunset.

After release from the nozzle, spray droplets are moved by their own velocity and the speed and direction of the encountered wind.

Large (COARSE) droplets have high velocity and little tendency to drift. However, small (FINE) droplets (<150 µm) are very easily picked up by wind and are prone to drift in the direction the wind is blowing.

It is advisable to reduce the number of FINE droplets with an appropriate nozzle selection and the choice of a drift-reducing adjuvant (e.g. LI 700®).

Where applicable, spraying should be undertaken with the wind blowing away from susceptible crops:

- To gain more flexibility from winds, spray with the coarsest spray quality possible without compromising efficacy
- DO NOT spray in winds that are too calm or too gusty. Spray when wind is steady and between 3 km/h and 20 km/h (15 km/h max. for 2,4-D products)
- DO NOT spray when the wind is blowing towards susceptible crops
- Measure and record local conditions at the time of application (e.g. WindMate or a tractor-mounted weather station)

TEMPERATURE

Temperature affects the application process indirectly by stressing the target organism. So therefore, a common label recommendation is not to spray when conditions are too hot or too cold.

Temperature also affects the application process directly by allowing highly volatile products to volatilise quicker, or, in combination with humidity, to affect droplet survival. Temperatures above 30°C should generally be avoided.

It is important to note that the standard temperature provided by the Bureau of Meteorology is measured 1.25 m above the ground. On hot days the actual ground temperature may be up to 20°C higher.

- To gain more flexibility from hot temperatures, spray with the coarsest spray quality possible without compromising efficacy
- Avoid spraying in temperatures above 30°C

WEATHER

SELECTING THE RIGHT DELTA T CONDITIONS FOR SPRAYING

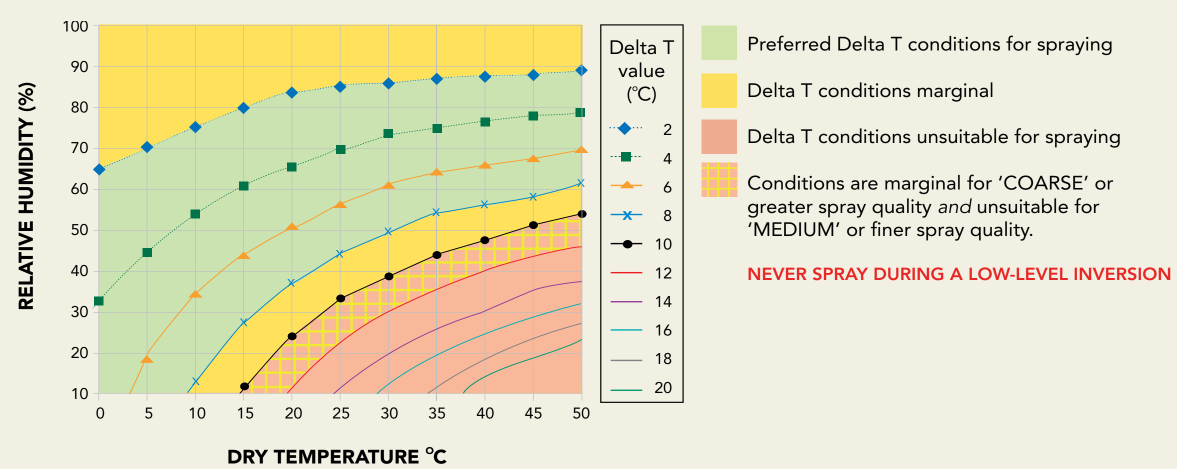


Figure 102

THEORETICAL SURVIVAL TIMES (SECONDS) OF WATER DROPLETS AT A RANGE OF WET AND DRY TEMPERATURE DIFFERENCES (DELTA ΔT)

		SURVIVAL TIME (IN SECONDS) DELTA ΔT (°C)								
		1	2	3	4	5	6	8	10	12
DROPLET DIAMETER MICRONS (µm)	10	1.25	0.63	0.42	0.31	0.25	0.21	0.16	0.13	0.1
	20	5	2.5	1.66	1	1	0.83	0.63	0.5	0.42
	50	31	16	10	8	6	5	4	3	3
	100	125	63	42	31	25	21	16	13	10
	200	500	250	167	125	100	83	63	50	42
	400	2000	1000	667	500	400	333	250	200	167

Figure 103

HUMIDITY

Humidity can affect application by influencing the evaporation rate of droplets. Its interaction with temperature can be expressed conveniently by Delta T (Figure 102).

DELTA T

In recent years, Delta T has become one of the most used standard weather indicators for acceptable spraying conditions. Delta T describes the relationship between relative humidity and dry temperature, and is calculated by subtracting the wet bulb temperature from the dry bulb temperature. In very dry and hot conditions, droplets evaporate extremely quickly.

The risk is chemical loss, because fine droplets may not even reach the target (Figure 103). Conversely, under cold, humid conditions, droplet survival may be extreme, with an increased risk of fine droplets drifting away. Optimum application conditions are when Delta T is between 2 and 8 (Figure 102). Conditions below 2 are marginal (extended survival of driftable fines). Delta T conditions above 10 should be avoided (too fast evaporation of droplets) unless a COARSE spray quality is used.

Delta T is only a guideline for ideal spraying conditions and importance may vary with the method of application:

- Delta T becomes more critical with lower water volume (<50 L/ha). Delta T becomes less critical with higher water volumes (>150 L/ha)
- Addition of adjuvants providing humectancy (e.g. Nufarm LI 700®, Nufarm Activator®, Nufarm Banjo®) will be beneficial under high Delta T conditions
- Preferred Delta T conditions in regards to efficacy and drift can be relaxed with coarser spray quality due to coarser droplets having more velocity and falling more quickly to the target. Coarser droplets have more volume and resist evaporation better than smaller droplets. In high Delta T conditions the limiting factor shifts from droplet survival to physiological limitations, such as plant heat stress

SMALL DROPLET BEHAVIOUR UNDER INVERSION CONDITIONS

Figure 104 *Typical inversion. 8:15 am Geraldton, Western Australia. Smoke from a smouldering chaff dump hits a capping inversion and moves approximately 2.6 km to a low-lying area. Photo: Bill Campbell.*

SMALL DROPLET BEHAVIOUR UNDER INVERSION CONDITIONS

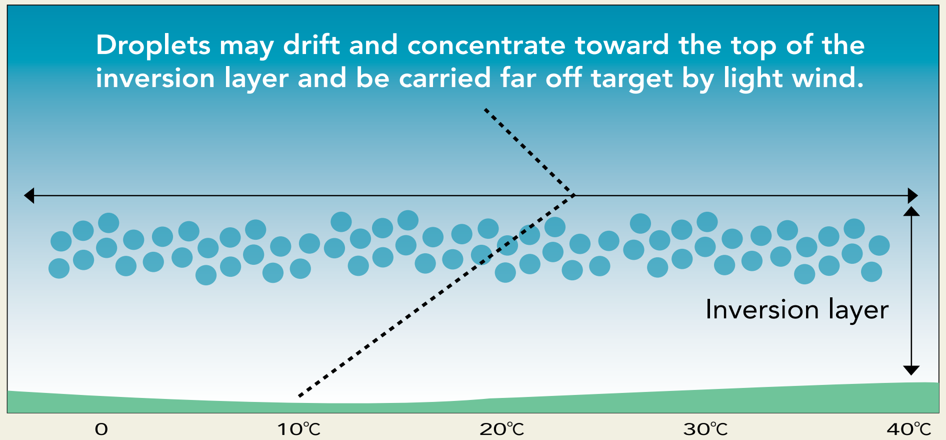


Figure 105 *Source: Graeme Tepper*

INVERSIONS

Surface temperature inversions occur when temperature increases with height, instead of the normal decrease with height. This is typically forced by a quick cooling of the earth's surface after sunset. Air layers close to the earth's surface cool faster than the air above. Cold air tends to sink, so the cold air close to the surface does not mix with the warmer air above it. Distinct, isolated layers of air are formed.

Visual indications are fog, dew, frost and smoke or dust hanging in the air or moving laterally in a concentrated package (Figure 104). However, absence of visual indicators does not mean there is no inversion. The onset of inversion gives rise to the often observed significant drop in wind speed near sunset.

In Australia, inversions occur most nights from early evening until several hours after sunrise. The greater the difference between maximum day and minimum night temperature, the stronger the inversion. Windy conditions are generally detrimental to the build up of inversions, so an inversion is more likely to occur on a calm night.

Isolated from the air layers above it, the inversion-layer's micro weather can be significantly different from the broader weather pattern as indicated by the weather forecast (Figure 106).

When spraying under inversion conditions, small driftable droplets or vapour may float in isolated, concentrated layers not subject to dilution with the atmosphere. The higher the humidity, the longer the survival of droplets. If these pockets are shifted by light katabatic winds (see page 65), common with inversions, a highly dangerous drift situation may develop:

- The greater the difference between daily maximum temperature and nightly minimum temperature, the greater the inversion will be and the longer it will take to erode
- Inversions are more likely in calm conditions and on clear nights
- Inversions are less likely in fresh, windy conditions or during heavy cloud coverage with or without rain

UNPREDICTABILITY OF WIND DIRECTIONS

Figure 106 *Source: Wayne State University*

LOCAL WEATHER EFFECTS: TOPOGRAPHY

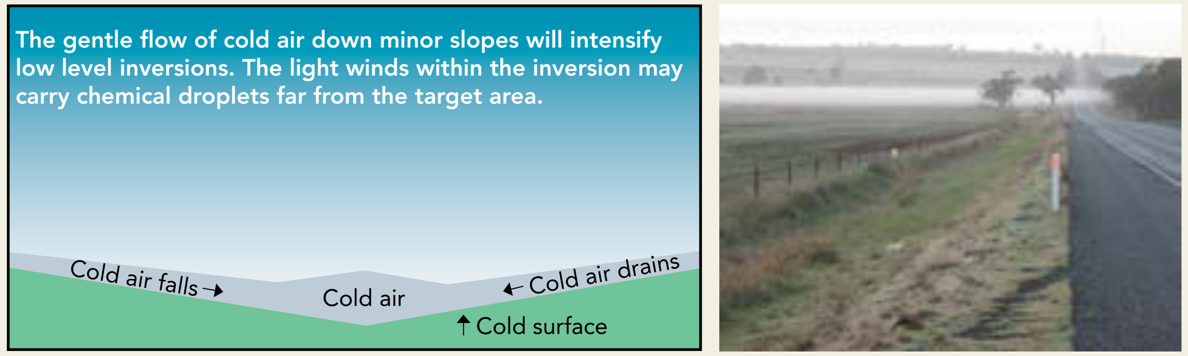


Figure 107 *Source: Graeme Tepper*

KATABATIC WINDS

Cold air becomes dense and heavy and, like water, drains to lower levels. This effect is especially strong under inversion conditions at night, when cold air gently drains down minor slopes. These inversion-induced winds can be influenced by distant topography and initially may even flow over flat terrain. Cool rivers of air pond in low-lying regions (Figure 107). Depending on terrain, the direction of windflow under inversion conditions may be opposite to the day wind direction, or the wind direction above the inversion (Figure 106). Significant wind shifts are likely between inversion and non-inversion conditions.

Cool air can move large quantities of suspended material into low areas. It is not uncommon for vapour or suspended droplets in an inversion layer to move long distances even causing damage 10 km away from the source of application.

Inversion conditions combined with katabatic winds introduce another set of highly unpredictable and dangerous drift scenarios:

- DO NOT spray in inversion conditions
- Use the coarsest spray quality without affecting efficacy to reduce the number of driftable FINE droplets
- Account for inversion-induced katabatic winds
- Avoid high humidity
- Use smoke devices for wind flow reference or tractor-mounted weather stations
- Use decision support tools that may predict inversions e.g. Spraywise Decisions® (see page 93)

ADJUVANTS

CHAPTER SUMMARY

- Adjuvants are substances that enhance or modify the performance of pesticides when added to the spray solution
- Adjuvants make the application process and chemical rates more robust

Pesticide label rates and formulations should be strong enough to handle some adverse conditions during the application process. However, during mixing, spraying, deposition and uptake of pesticides, losses can be so substantial that efficacy is compromised. Adjuvants can overcome many of those problems. Essentially, they make the application process more robust. For many products the use of adjuvants is optional but for some chemistry particular adjuvants are essential to assure performance.

For example, most selective grass herbicides will need the addition of oil, unless crop safety is a concern. In case of the latter, higher product rates are generally used to overcome the lack of oil.

It is important to choose the right adjuvant for a specific task.

This process is complex and often it is not easy for the applicator to fully understand the functional role of a particular adjuvant. An ever growing number of registered products, many with dubious claims, create additional mystery, resulting in a 'snake oil' perception of adjuvants.

By definition, adjuvants are substances that enhance or modify the performance of pesticides when added to the spray solution. Most useful adjuvant classification are based on the functionality of the adjuvant (see Figure 108).

ADJUVANTS: FUNCTIONAL CLASSIFICATION

WETTING/SPREADING AGENTS	
CONVENTIONAL SURFACTANTS	• Anionic surfactant: a surface-acting agent that forms a negative ion (anion) at its lipophilic part when in solution with water • Cationic surfactant: a surface-acting agent that forms a positive ion (cation) at its lipophilic part when in solution with water • Non-ionic surfactants: a surface-acting agent that has no ionisable polar end groups, e.g. Activator®, Chemwet 1000
ORGANOSILICONES	Pulse®, Du-Wett®, Designer®
PENETRATION AGENTS	
OILS	• Petroleum or Mineral Oils: a) containing > 95% mineral oil and < 5% emulsifier, e.g. D-C-Tron® (1-3%) or D-C-Trate® (< 5%) b) containing < 85% mineral oil and > 15% emulsifier, e.g. Uptake®, Supercharge® • Vegetable Oils: a) Vegetable oil with < 15% emulsifier, e.g. Synertrol b) Chemically modified vegetable oils (methyl or ethyl esterfied) with emulsifier, e.g. Banjo®
LECITHIN	LI 700
SURFACTANTS	• Conventional surfactants at high dose (> 0.15% v/v) e.g. Activator, Chemwet 1000 • Organosilicones, e.g. Pulse
STICKER/ADHESION AGENTS	
SURFACTANTS	Wetter TX, Activator, Chemwet 1000, LI 700
LATEX AND RESIN TYPE ADJUVANTS	Designer, Bond
WATER MANAGEMENT AGENTS	
pH MANAGEMENT BUFFERS	a) Acidifier (e.g. LI 700) b) True Buffer (e.g. Primabuff®) c) Alkaline agents
HARD WATER MANAGEMENT AGENTS	Liase®
ANTIFOAM/DE-FOAM AGENTS	Activator
SUSPENSION/RE-SUSPENSION AGENT	
COMPATIBILITY AGENTS	Flowright
DRIFT REDUCING AGENTS	
LECITHIN	LI 700
OILS	Banjo
LATEX	Bond®
MISCELLANEOUS AGENTS	
HUMECTANTS	LI 700, Activator
EXTENDERS	Prolongs the activity of chemicals in adverse weather conditions, e.g. Bond
SPRAY INDICATORS	Spraymarker Dye
FOAM MARKERS	Foammarker Pink

Figure 108

ADJUVANTS AND WATER QUALITY

CHAPTER SUMMARY

- Water quality becomes less of an issue with robust chemical rates and/or lower water rates
- Test the water quality throughout the season
- Most pesticides perform best in slightly acidic conditions
- Manage water with high pH with Nufarm LI 700
- Manage hard water with Liase
- Manage bicarbonates with Liase to protect DIM chemistry
- Manage bicarbonate problems for 2,4-D amine by using MCPA formulations or LV ester formulations over 2,4-D amine formulations where practical
- Avoid or filter muddy water
- If using a saline water source, boost and protect suspension systems in formulation by adding additional adjuvants such as Nufarm LI 700 and Nufarm Liase

GENERAL

Pesticide formulations are designed to be mixed with water as the primary dilutent and carrier. Water itself is an active chemical usually comprises the largest percentage of the spray solution. Water quality can interfere significantly with the performance of pesticides.

The main factors affecting water quality when using agricultural chemicals are pH, hardness, salinity and bicarbonates. It is important to know of the quality of each water source used. pH and hardness can easily be tested with test strips in the field. Other factors such as bicarbonate levels have to be tested in a laboratory. Potential water quality problems can often be overcome with adjuvants:

- Water quality can change over time and measurements should be taken throughout the season
- Manage water quality with adjuvants where possible

MANAGING HIGH PH

pH provides a measure of the hydrogen ion concentration of a solution and ranging from 0 to 14. The pH value stands for p(otential of) H(ydrogen). In pure water the concentration of hydrogen ions is equal to 0.0000001, or 10^{-7}moles per litre = pH 7 = log10(10^{-7}). This is considered a neutral solution. If the concentration of hydrogen ions increases the solution becomes acidic and the pH drops below 7. For example, a strongly acidic solution with pH 2 represents a concentration of 0.01 or 10^{-2} moles per litre hydrogen ions. Acidic solutions have values below 7. Alkaline, or basic, solutions have values above 7 and contain less hydrogen ions than neutral solutions.
Most pesticide formulations perform best in slightly acidic conditions around a pH of 5. This can create problems if the water source is alkaline (for example the majority of bore water sources or water stored in concrete tanks).

Only few pesticides work best in alkaline conditions, e.g. copper.

ALKALINE HYDROLYSIS

In alkaline water, some chemicals are broken down rapidly by irreversible chemical reactions - alkaline hydrolysis. Alarming example of rapid breakdown is the insecticide dimethoate. Half of the product will be irreversibly destroyed within minutes in an alkaline spray solution of pH 9. (Figure 109).

DISSOCIATION OF ACIDIC HERBICIDES

Weak acidic herbicides such as glyphosate are least likely to be taken up by the plant if they are present as a strongly charged molecule. An alkaline environment (pH above 7) increases the amount of weak acidic herbicide present in the electrically-charged ionic form. To optimise uptake it is advisable to lower the pH.

The pH of a spray solution doesn't just depend on the water source and chemical. The leaf surface of many weed species is alkaline, especially broadleaf weeds like wild radish. This can change the pH of a droplet once it starts interacting with the plant surface.

ACIDIFYING

Detrimental pH effects can be easily minimised by acidifying the spray solution with LI 700 at a rate of 100 ml/100 L. LI 700 contains propionic acid. Its acidifying and buffering properties not only protect many pesticides from chemical breakdown in the tank but also provide a more favourable pH environment on the leaf surface for chemical uptake.

ALKALINE HYDROLYSIS

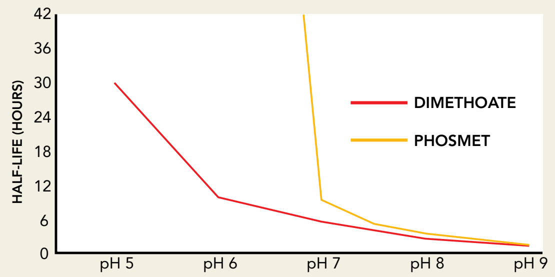


Figure 109

EFFECT OF CALCIUM ON GLYPHOSATE UPTAKE IN *SETARIA* (PIGEON GRASS)

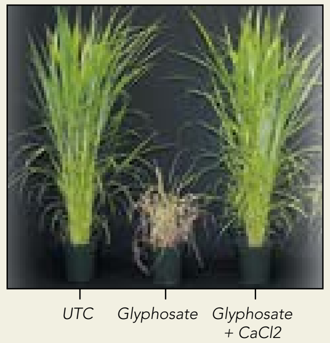


Figure 110

ANTAGONISTIC BEHAVIOUR OF CALCIUM IONS WITH GLYPHOSATE

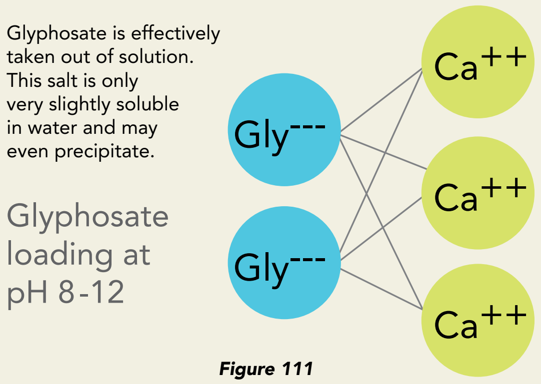


Figure 111

MANAGING WATER HARDNESS WITH LIASE

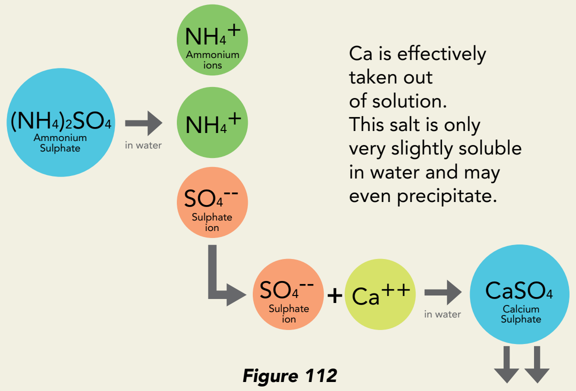


Figure 112

MANAGING WATER HARDNESS

Hardness is caused by an abundance of positively charged metal ions, usually Ca^{++} and Mg^{++}. These ions can bind strongly to negatively charged weak acidic herbicides such as glyphosate and greatly hinder their performance (Figures 110 & 111). Hardness is measured in ppm (parts per million), with water generally classified as hard at 300 ppm and above. Many Australian water sources have a degree of hardness in excess of 1000 ppm.

Adding Liase will overcome hard water measuring more than 300 ppm. Liase is a high quality aqueous solution of ammonium sulphate.
The negatively charged sulphate ions bind with Ca^{++} ions and effectively take them out of the solution (Figure 112):

- Hard water above 300 ppm should be managed with Liase

MANAGING BICARBONATES

Another group of water-suspended salts that can interfere with performance of chemicals are bicarbonates. Bicarbonate (HCO_3^-) is released naturally from chemical weathering of rocks into ground water. Many trials have shown that water containing bicarbonates at concentrations as low as 250 ppm can lower the efficacy of DIM herbicides (Group A) such as Achieve® or Select (Figure 115). FOP chemistry, e.g. Fusilade, is not affected by bicarbonates. Currently it is not possible to test for bicarbonates in the field.

However, adding 2 L/100 L of Liase provides a cost-effective and simple solution. Considering the cost of DIM herbicides, the use of Liase is an excellent insurance policy against adverse water conditions. Another chemical affected by bicarbonates is 2,4-D, but adding Liase does not improve the problem. Possible solutions are to use MCPA or LV ester formulations instead of 2,4-D amines:

- Bicarbonates can be managed with Liase to protect DIM chemistry
- Bicarbonate problems for 2,4-D can be managed by using MCPA formulations or LV ester formulations over 2,4-D amine formulations where practical

SUSPENSION STABILITY

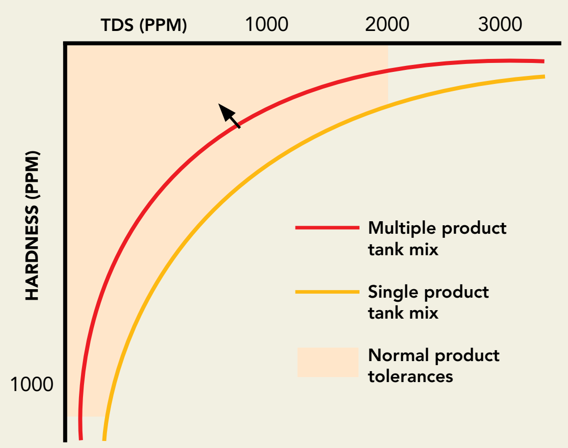


Figure 113

BREAKDOWN IN A FLOWABLE SUSPENSION UNDER UNFAVOURABLE WATER CONDITIONS (HIGH PH)

Figure 114

MANAGING SALINITY

Salinity is difficult to manage. It is caused by abundance of sodium chloride (cooking salt) and measured in ppm. Generally saline water should be avoided or shandied with good quality water, especially when using sensitive chemical formulations or mixtures.

MANAGING SUSPENSION STABILITY

Most pesticides contain dispersing surfactant (see page 79) systems to disperse the chemical in the water and keep the active in suspension.

Water hardness, salinity, bicarbonates, high levels of Total Dissolved Solids (TDS) and alkaline water conditions can all put the suspension system under stress and affect the mixing performance of a chemical. These unfavourable water conditions may use up part of the surfactant system leaving in insufficient surfactant to keep chemicals in suspension (Figure 114).

Using Liase and/or LI 700® according to the water problem will reduce the risk of suspension failure by improving water quality and by providing additional strength to the suspension system. Liase should be considered, especially when mixing ordinary glyphosate mixtures with flowables, such as simazine and atrazine:

- High levels of TDS in water can interfere with suspension stability
- Boost and protect suspension systems in formulation by adding additional surfactants such as LI 700® and Liase
- Avoid the use of three or more products in a tank mix (Figure 113)

WATER BICARBONATE EFFECT ON DIM HERBICIDE

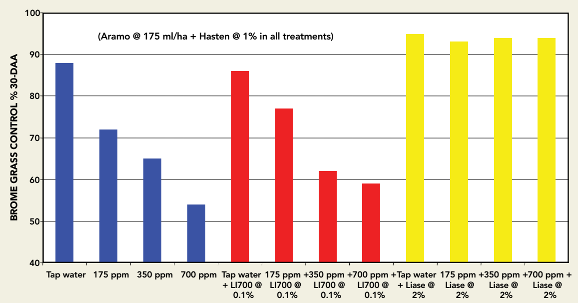


Figure 115 *Source: Nufarm (average of two trials)*

BUCKET TEST

Figure 116

MUDDINESS

Heavy clay content in some water sources will interfere with glyphosate or bipyridyl chemistry. Water is considered to be too muddy when a 20 cent coin can't be seen on the bottom of a standard 9 L bucket (Figure 116):

- If possible, filter muddy water or change water source
- Use robust chemical rates and lower water volumes in marginal quality water

ADJUVANTS AND WATER QUALITY

SUMMARY TABLE

ACTIVE/PRODUCT	HARDNESS	BICARBONATE	SALINITY	MUDDINESS	ALKALINITY
2,4-D ester (Estercide® Xtra 680)	Liase				
2,4-D amine (Amicide® Advance 700)	Liase				LI 700®
Chlorsulfuron (Lusta®)	Liase				
Clethodim (Sequence®)		Liase			
Clopyralid (Archer®)	Liase				LI 700
Dicamba Amine (Kamba® M)	Liase				LI 700
Picolinafen/MCPA (Paragon®)	Liase				LI 700
Diuron	Liase				LI 700
Diuron + 2,4-D amine (Amicide Advance 700)	Liase				LI 700
Diuron + MCPA (Agritone® 750)	Liase				LI 700
weedmaster® DST	Liase				LI 700
Credit® + Bonus®					
Agritone 750	Liase				LI 700
LVE Agritone	Liase				
Diquat/Paraquat (Revolver®)					
Simazine WG	Liase				
Tralkoxydim (Achieve®)		Liase			
Chlorpyrifos EC					LI 700
Alpha Cypermethrin EC (Astound® Duo)					LI 700
Dimethoate EC					LI 700

Recommendations depend upon the severity of the problem.

Liase	LI 700		
Can be managed with Liase	Can be managed with LI 700	Generally no problem	Water should be avoided

Figure 117 *Water Quality Management*

ADJUVANTS AND SPRAY QUALITY

CHAPTER SUMMARY

- Avoid non-ionic surfactants
- Use drift-reducing adjuvants such as LI 700® or Banjo drift-neutral products such as Activator

EFFECT OF ADJUVANTS ON SPRAY QUALITY

Figure 118 *XR TeeJet®110-02 nozzle type sprayed at 2.5 bar*

The formation of spray droplets is influenced by three main factors - nozzle type, pressure and the nature of the spray solution plays an important role as well.

The final spray solution consists of water, the chemical used (including its inert adjuvant system), extra added adjuvants and possibly other additives such as liquid fertiliser. All of these factors can have a profound effect spray quality. The applicator may have little knowledge of the inert adjuvant system of a formulation but has direct control over the choice of adjuvants.

The main aim is to select a combination that produces the coarsest spray quality without compromising efficacy.

Commonly used non-ionic surfactants generally increase the number of droplets in the fine spectrum, increasing the risk of drift and decreasing operational flexibility (Figure 118).

These products should be avoided and whenever possible, be substituted with adjuvants that have the opposite effect.

Several independent studies have shown that LI 700® decreases the number of undesirable very fine droplets that are prone to drift (Figure 118 - 120).

LI 700® reduces the number of undesirable very large droplets that are detrimental to good coverage and prone to shattering when they reach their target. Generally, LI 700® narrows the droplet spectrum at both ends of the size spectrum and increases the number of droplets in the desirable range.

Most oils will generally have a similar but more variable effect on the droplet spectrum, depending on their nature and the nozzle type used.

Choosing the right adjuvant is an excellent tool for droplet management, but is not a substitute for the right nozzle choice. Choosing the right adjuvant should add to the solution not to the problem.

REDUCTION OF DRIFTABLE FINES WITH LI 700 SPRAYING A GLYPHOSATE FORMULATION

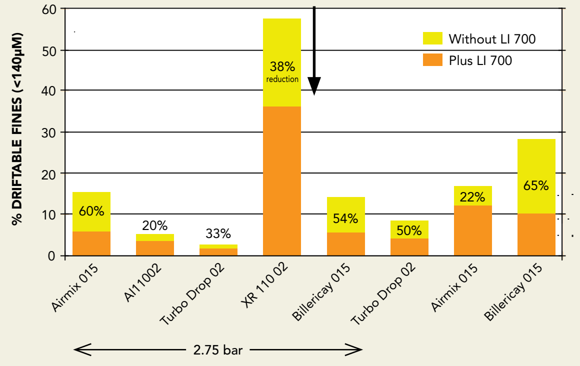


Figure 119 *Source: The Centre for Pesticide Application and Safety, Gatton, New South Wales 2006.*

ADJUVANTS AND DEPOSITION

CHAPTER SUMMARY

- Adjuvants provide elasticity and adhesion
- Consider using special deposition and retention agents for fungicide applications
- When using a coarser spray quality with coverage sensitive products, increases water rates to counteract potential problems

It is well documented that droplets on foliar impact may:

- Bounce off or be reflected
- Shatter or be fragmented
- Run-off or drain from the leaf
- Be retained

Droplet behaviour can account for large losses of pesticide during application. Waxy plant cuticles, especially when they are positioned upright or overhanging, can be difficult for droplets to adhere to

EFFECT OF ADJUVANTS ON DRIFTABLE FINES

Figure 120 *Application with XR TeeJet®11002 at 2 bar*

DROPLET BEHAVIOUR: BOUNCE

Figure 121 *Source: Lovelands*

IMPACT OF SPRAY QUALITY ON RETENTION

The main concern lies with larger droplets. Small droplets have little velocity, fall slowly and their energy level at moment of impact is low.

They tend to stick to the leaf. However, even small droplets may not stick to extremely waxy leaves or the lower side of broadleafed plants (important for surface-acting fungicides and insecticides).

In theory large droplets fall faster, have high momentum at time of impact and are more likely to bounce or roll off (Figure 121).

However, most of the coarser spray qualities will be produced with air induction nozzles. Those droplets will be filled with air inclusions that serve as a type of shock absorber reducing bounce and shatter and reducing velocity.

In dense canopies some bouncing, shattering and run off can be desirable to improve coverage in the lower canopy.

If recommendations are followed, deposition volumes from COARSE droplets of herbicides on most broadleaf plants should be similar to finer droplets; especially if used with adjuvants. Grasses are generally harder to wet, so coarse droplets may need the addition of surfactants.

IMPACT OF ADJUVANTS ON RETENTION

Deposition behaviour of droplets can be significantly improved with adjuvants. Adding an adjuvant almost always has a beneficial effect on deposition. The dynamic surface tension of droplets is lowered by the surfactant loading that most adjuvants have. This increases elasticity and adhesion and increases initial deposition by being sticker.

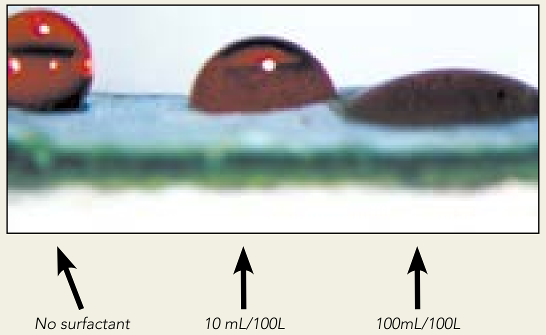
The level of additional retention will vary greatly with products. Products such as Wetter® TX (use with herbicides on small grasses) or Bond® (use with fungicides and insecticides) are especially effective. Du-Wett® and Designer® are excellent in orchard and vegetable situations.

ADJUVANTS AND SPREAD

CHAPTER SUMMARY

- Spread is critical in many situations but not in others it is not – it may even be detrimental
- DO NOT use organosilicones for general spreading purposes as they are specialized products for specific situations. Follow label recommendations

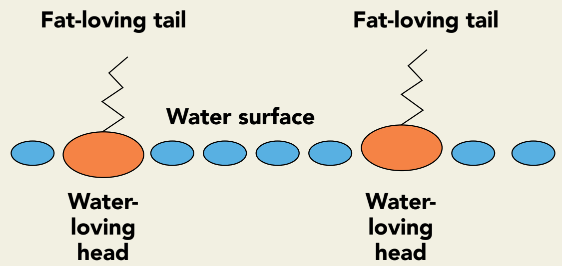
DOSE RESPONSE OF NON-IONIC SURFACTANT AGRAL 900 ON DROPLET SPREAD (CABBAGE)



Reducing the surface tension value of water will result in droplets that will flatten or spread on the surface upon which they reside. The extent of droplet spread is dependent on the amount of surface tension reduction (dose of surfactant), the nature of the surface of the leaf and the characteristic of the surfactant hydrophobic "tail". Up to a certain concentration spread will increase (in this case around 100 mL/100L). After this point is reached, more spread is not possible.

Figure 122 *Source: Michigan State University, Michigan, USA*

HOW DO SPREADERS (SURFACTANTS) WORK?



Surfactant molecules force water molecules apart which weakens the attractive force (surface tension) between them.

Figure 123

SPREAD

At least some coverage of the leaf surface is critical for the performance of many pesticides. The inert surfactant systems of products as well as added adjuvants are important tools for increasing the spread of droplets once they have landed on the plant surface.

The word surfactant originates from surface acting agents. Typically, surfactant molecules consist of two distinct parts: a water-soluble head and a fat/oil-soluble tail, similar to soap. Surfactants are amphiphilic (they love both water and oil). Once in water the fat-loving (lipophilic) but water-hating (hydrophobic) part of the molecule is pushed out towards the surface of the water droplet (Figure 123). As a result, the surfactant forces water molecules apart, weakening the attractive force that creates surface tension. This causes the droplet to collapse from its spherical shape and flatten out, covering more of the leaf surface (spreading).

The extent of droplet spread is dependent on the nature of the leaf surface and the dose and characteristics of the surfactants (Figure 122 & 124).

HYDROPHILIC LIPOPHILIC BALANCE (HLB)

Surfactant differences are often in the length of the tail and size of the head. The longer the tail (number of carbon atoms), the more pronounced the hydrophobic aspect of the product. The bigger the head (number of ethoxy groups), the more pronounced the hydrophilic aspect.

The molecular balance of the hydrophilic and lipophilic groups is the HLB (hydrophilic lipophilic balance). The HLB is a good indicator of surfactant performance.

Highly ethoxylated surfactants are very polar interacting very well with water but poorly with wax. They are excellent spreaders and often used as horticultural adjuvants, e.g. Agral®. However they are ineffective penetrants. By contrast, surfactants with a balance shifted towards the lipophilic end are less effective spreaders but better penetrants.

ADJUVANTS AND SPREAD

PLANT SURFACE AFFECTS SPREAD

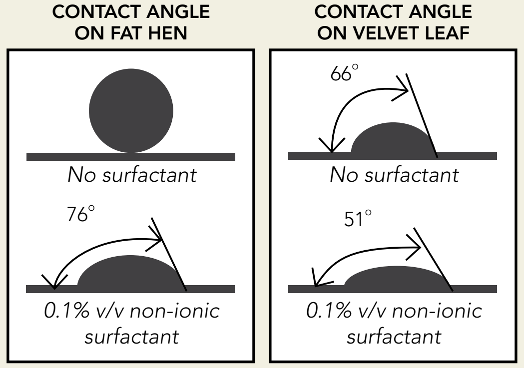
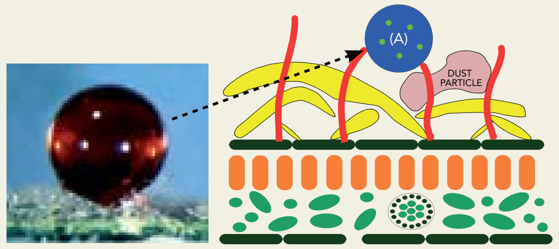


Figure 124

HEADING



Droplet (A), containing pesticide and water, may be held from close contact on the living tissue by dust, hair or the waxy cuticle.
Absorption of the active pesticide into the leaf will be slow.
Photo: Water on Apple Leaf by Bukovac – Michigan State University, Michigan, USA

Figure 125

CRITICAL MICELLE CONCENTRATION: CMC

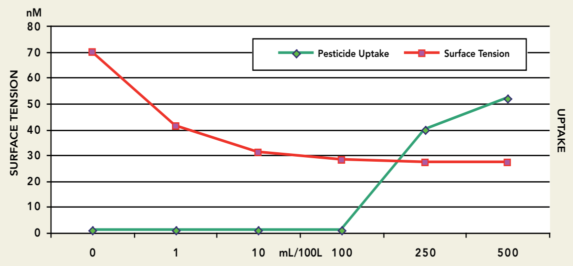


Figure 126

LI 700 LIPID BILAYER MICELLE STRUCTURE

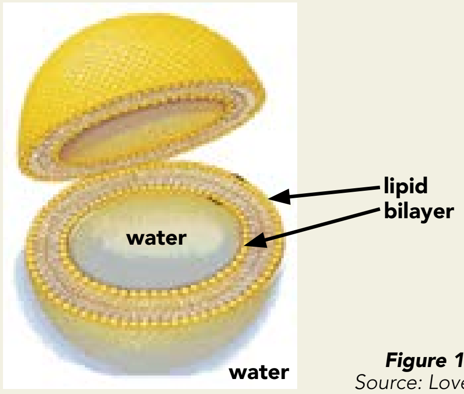


Figure 127
Source: Lovelands

RATE DEPENDENCE

Reduction of surface tension by surfactants is rate dependent up to a point of maximum effect.

For most surfactants this will occur at or below 100 mL/100 L (Figure 126). Adding more surfactant will not increase droplet spread. At rates above this point the hydrophobic ends of surfactants are not only pushed to the droplet surface but increasingly pushed towards each other, forming globular or cylindrical structures called micelles (Figures 127 & 128). These micelles can contain active, interact with waxy cuticles and increase uptake.

This is the reason why non-ionic surfactant rates to improve glyphosate activity are often 200 mL/100 L (Figure 126).

Many horticultural wetters have a label rate of 10-20 mL /100 L. At that rate the increase in spreading does virtually not exist and the reason for their use has to be questioned (may be a slight increase in deposition?). Wetters should be used at a rate of 100 mL/100 L if spread of droplets is a prime concern. Unfortunately at that rate most of them increase foaming and drifting. Activator® has a legal 100 mL/100 L label rate, stops foaming and does not increase the production of driftable fines.

MICELLES

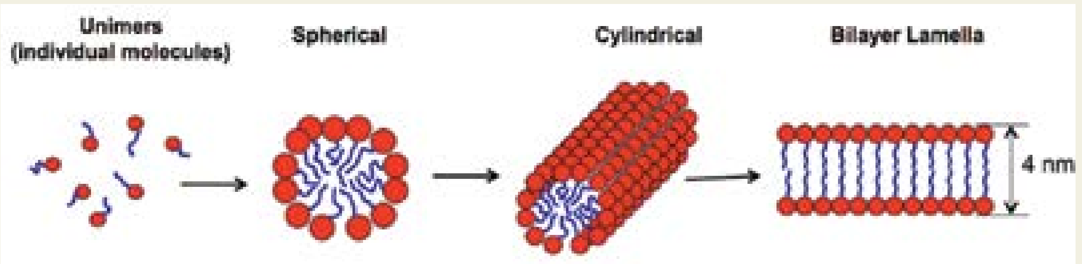


Figure 128

ADJUVANTS AND HUMECTANCY

ARG – SPREAD OF DROPLET CONTAINING PULSE

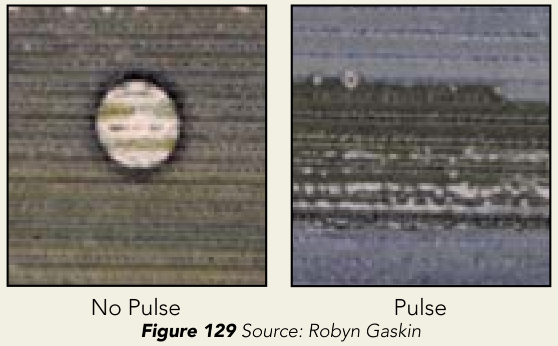


Figure 129 Source: Robyn Gaskin

GORSE SURFACE – HARD TO WET

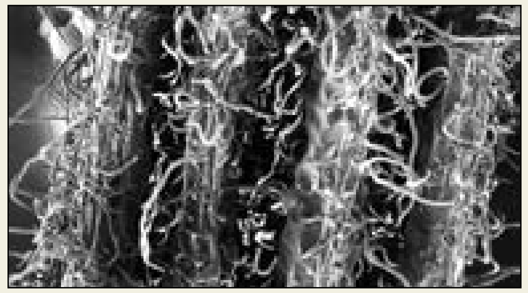


Figure 130 Source: Robyn Gaskin

ORGANOSILICONES

Organosilicones are super wetter surfactants. A product such as Pulse® reduces surface tension of water to extremely low levels and provide up to 12 times more spread than conventional wetters (Figure 129). For herbicide applications they are specialized, indispensable tools to achieve coverage in difficult situation, e.g. woody weeds (Figure 130).

However, for most fungicide and insecticide applications in vineyards, orchard and vegetable crops organosilicones are too unpredictable in terms of crop safety. In these situations the special hort superspreaders Nufarm Du-Wett® or Designer® are for concentrate spraying.

HUMECTANCY

Aqueous solutions of ionic compounds, glyphosate in particular, benefit from prolonged drying times on the leaf surface to optimise uptake (Figure 131). This can be achieved by using a coarser spray quality and adjuvants that provide humectancy. Humectancy enables a droplet to remain wet or liquid for an extended period.

Lecithin-based adjuvants such as LI 700®; oils such as Banjo®; or specialized non-ionic surfactants enhanced with glycol and fatty acids, such as Activator®, provide the droplet with a hydration sheath that prolongs drying time (Figure 131). Humectancy is particularly important during hot conditions (e.g. in summer spraying).

In contrast, the uptake of non-ionic compounds relies mainly on diffusion through the waxy cuticle as these chemicals normally contain a high level of inert solvents that provide a sufficient film on the leaf surface. In general, the uptake of non-ionic actives is less dependent on surface wetness (Figure 133).

ADJUVANTS INFLUENCE DRYING TIME AND UPTAKE: HUMECTANCY

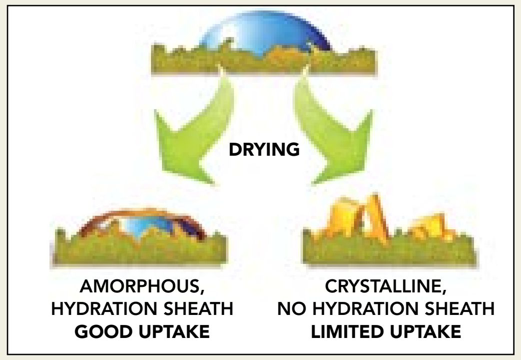


Figure 131 Source: Loveland

ENTRY OF IONIC COMPOUNDS VIA AQUEOUS PATHWAY

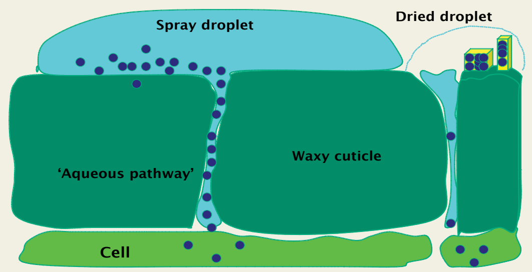


Figure 132

ENTRY OF NON-IONIC COMPOUNDS VIA WAX

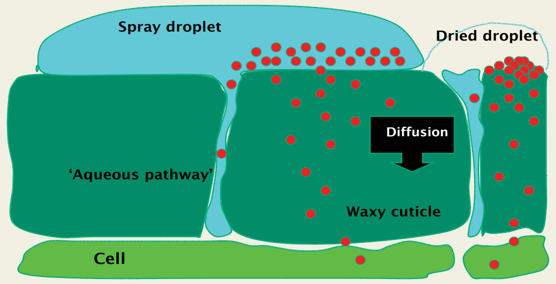


Figure 133

CHAPTER SUMMARY

- Adjuvants are critical for systemic pesticides to overcome the hurdle of entering the waxy plant cuticle
- Be aware of possible crop effects that different adjuvant types may cause
- Specific chemicals may benefit most from specific adjuvants. Follow label directions and manufacturer's advice
- Observe minimum label rates required, e.g. 250 mL/100 L for LI 700®

PENETRATION

Once on the leaf surface, the most difficult hurdle for systemic pesticides is entry into the leaf through the waxy plant cuticular. Layers and layers of hydrophobic waxes protect the moist inside of the plant. Barriers are related to the form, thickness and chemical make-up of these waxes. Permeability may vary thousand fold between plant species.

There are several mechanisms by which adjuvants can enhance the transport of pesticides across this limiting layer. For many chemicals, choosing the right adjuvant is critical to optimise penetration into the plant so always follow label directions. Optimised uptake will not only affect the overall diffusion rate but also the speed of uptake and therefore rainfastness.

PASSIVE DIFFUSION VIA THE LIPID PATHWAYS OF THE FATTY CUTICULA

Lipophilic actives, in particular, rely on this form of uptake. A high concentration of active on the plant surface drives diffusion into the mostly lipophilic environment of the cuticle. At this stage adjuvants can help optimise the process by providing an environment favouring undissociated molecules that are generally the preferred form for penetration (Figure 133).

PASSIVE DIFFUSION VIA THE AQUEOUS PATHWAY

Within the lipophilic environment of the cuticle is an additional pathway that is much more hydrophilic aqueous pores. These small channels (<1 nm) are permeable to water and small ionic molecules such as glyphosate. The rate of transport depends on surface wetting, the length of the channel and ion binding resistance along the walls of these very narrow pathways. Adjuvants can assist this form of uptake by providing prolonged drying times and by optimising the chemical environment in the spray solution (Figure 132).

ACTIVE TRANSPORT THROUGH EXISTING PHYSICAL OPENINGS

Morphological openings in plants are minute. So flooding of spray solution into those openings is only possible when surface tension is reduced to very low levels such as those achieved by high rates of organosilicones (e.g. Pulse®). Sites of entry include stomata, cracks, crevices, pores or physically damaged areas. Stomatal uptake can be limited due to their location of stomata and to the time they are actively open.

ACTIVE CUTICULAR DISRUPTION

Adjuvants can actively decrease the barrier properties of waxes and create pathways by cuticle disruption. The disruption is primarily by surfactant micelles. Adjuvants can reduce the viscosity and melting points of surface waxes (by plasticising or softening). A less viscous environment makes it easier for actives to be taken up and results in higher diffusion rates. This is especially important at low temperatures when waxes are very stiff, or for plants growing in dry conditions.

The disruption can be soft and temporary. For example, when the joining points of crystalline wax platelets are loosened, then resettled. However, effects can be permanent and may result in a complete meltdown of the wax structure leading to a removal or stripping effect. To accomplish this accelerating effect of adjuvants it is important to use recommended label rates: non-ionic surfactants e.g. Chemwet® 1000, 200 mL/100 L; lecithin-based sprays (e.g. LI 700, a minimum of 250 mL/100 L); oil-based sprays e.g. Banjo®, a minimum of 0.5 L/100 L; and enhanced non-ionic surfactants e.g. Activator® at 125 mL/100 L.

ADJUVANTS AND PENETRATION

LI 700 vs OIL – EFFICACY WITH GLYPHOSATE

Figure 134 *Control of Button Grass with 1.4 L/ha Glyphosate 450*
**Oil @ 1 L/100 L + Wetter @ 100 mL/100 L + AMS @ 1 L/100 L*
***LI 700 @ 200 mL/100 L*
Pictured: Yuna, W.A. Source: Bernie Quade (Landmark)

DIFFERENCE BETWEEN VEGETABLE OIL AND LECITHIN (ACTIVE IN LI 700)

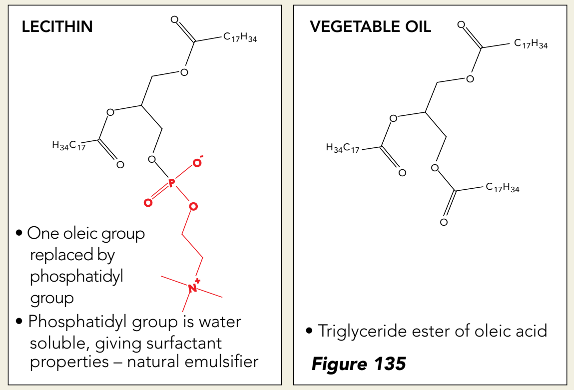


Figure 135

PENETRATION AND MANUFACTURER'S ADVICE

GLYPHOSATE EXAMPLE

Certain pesticides benefit most from specific penetrants. So it is important to follow manufacturer's advice.

For example, glyphosate labels generally don't recommend the use of oils, but do recommend the addition of lecithin based adjuvants, such as LI 700®, or non-ionic surfactants.

Oils will increase droplet survival in hot conditions and prolong drying times of glyphosate on the leaves. They will loosen waxy cuticles and may increase the uptake of glyphosate in some situations. However, oils are hydrophobic and don't like to interact with polar components such as glyphosate or water. They need emulsifiers to enable mixing with water and their performance greatly depends upon their emulsifier load.

The interaction of oil and glyphosate is limited and variable. Control of grasses particularly in the summer can be compromised by using oils (Figure 134).

On the other hand, lecithin is itself an emulsifier. It has two long carbon chains that give the molecule its lipophilic character and one polar phosphatidyl group that gives the molecule its hydrophilic character (Figure 135), enabling it to mix readily with polar compounds such as water or glyphosate. Like oil, lecithin will provide prolonged drying times and droplet survival, and will loosen the waxy cuticles.

Sometimes glyphosate is tank mixed with a mixing partner that requires the addition of an oil. In that situation the benefit to the efficacy of the mixing partner may out weigh the potential negative effect of the oil on the glyphosate. In these situations an oil may be used as long as the applicator is aware of the potential for reduced grass control.

HEADING

GENERAL TECHNICAL FIT		LIASE	CHEMWET 1000		WETTER TX	ACTIVATOR®		LI 700®		BANJO®	BOND®	PULSE®	DU-WETT®	DESIGNER®
			LOWER RATES	HIGHER RATES		LOWER RATES	HIGHER RATES	LOWER RATES	HIGHER RATES					
WATER CONDITIONING	HIGH pH							✔✔	✔✔✔					
	HARDNESS	✔✔✔												
	ANTI-FOAMING			✘	✘	✔✔	✔✔✔						✘	
	COMPATIBILITY	✔✔						✔	✔					
DROPLET MANAGEMENT			✘	✘✘	✘✘	NEUTRAL	NEUTRAL	✔✔	✔✔✔	✔✔	✔✔		NEUTRAL	✔✔
DEPOSITION AID			✔	✔	✔✔	✔	✔	✔	✔	✔	✔✔✔✔	✔	✔✔	✔✔
SPREADING			✔✔	✔✔	✔✔✔	✔	✔✔	✔	✔✔	✔✔	✔	✔✔✔✔✔✔✔✔	✔✔✔✔✔	✔✔✔
PENETRATION	SYSTEMIC PRODUCT			✔	✔		✔✔		✔✔✔	✔✔✔		✔✔✔✔		
	SURFACE ACTIVE													
RAINFASTNESS	SYSTEMIC PRODUCT			✔	✔		✔✔		✔✔✔	✔✔✔	✔	✔✔✔		
	SURFACE ACTIVE										✔✔✔✔✔✔			✔✔✔✔
TRANSLOCATION		✔✔							✔					

Figure 136 *Adjuvants and their technical fit* ✔ Better effects indicated by higher number of ticks; **NEUTRAL** indicates no effect; ✘ indicates that the adjuvant has a negative effect on the outcome. A blank square, or no fill, means no effect expected.

CHAPTER SUMMARY

- Be aware of the physical compatibility of the products you are using
- If in doubt, conduct a jar test
- Follow manufacturer's guidelines
- Follow the mixing order

AGROCHEMICAL FORMULATIONS

The chemical and physical properties of an active ingredient, such as solubility in various solvents, susceptibility to degradation, melting point, acidity or alkalinity etc, often dictate the most suitable type of formulation. Formulation types include:

- Wettable Powders (WP)
- Water Dispersible Granules (WDG)
- Dry Flowables (DF)
- Flowables or Suspension Concentrates (SC)
- Emulsifiable Concentrates (EC)
- Soluble Liquid Concentrates (SLC)
- Water Soluble Granules (WSG)

The key differences between formulations are the type of delivery systems used - solvents and surfactants that provide both physical and chemical stability. These are the product-specific components most likely to be affected by mixing multiple products.

SURFACTANT SYSTEMS

Surfactants produce stable emulsions or suspensions that enable homogeneous application of chemicals. Differences in the nature of surfactants make them suited to different formulation types, e.g. different surfactants are used in emulsion concentrates compared with suspension concentrates.

The key parameter determins suitability of a surfactant for a particular type of formulation is the HLB (see page 74). Chemical actives are assigned a typical HLB, which is then used to select an appropriate surfactant of similar HLB. Often a blend of two or more surfactants is used, with an average HLB at the required value to improve stability over a wider range of water qualities. The amount of surfactant is also very important for each particular product to perform as intended in the field.

When mixing products, the final HLB may be unsuitable for one or more of the components - resulting in poor suspension or emulsion characteristics.

This may cause layering, settling or gelatinous materials blocking filters - which referred to as antagonism. Adding adjuvants such as spray oils (which may not contain very much surfactant) may produce a similar effect - referred to as surfactant overload. Surfactant overload occurs when there is insufficient surfactant reserve in the formulation to cope with the addition of oil.

THE IMPORTANCE OF MIXING ORDER FOR AGROCHEMICALS

The manner in which a surfactant and active interact with each other when added to water in the spray tank is critical to reaching a stable emulsion or suspension.

WETTABLE POWDERS

These must be added to the water first because they have a very large surface area to be wetted. For these particles to be dispersed as individual particles of the right micron size to ensure a stable suspension, the surfactant system for that particular active should not be compromised by the presence of surfactants of differing HLB or, a lipophilic (oily) substance.

WATER DISPERSIBLE GRANULES OR DRY FLOWABLES

These require a similar process to Wettable Powders. In this case, the granules need to disintegrate into individual particles to form the suspension.

As granules are heavier than powders, they break the surface of the water and sink towards the bottom of the tank. If they contact oily materials prior to complete disintegration, the suspension stability is compromised.

FLOWABLES

These contain particles already wetted, but in a concentrated, slurry form. These particles disperse and suspend at a faster rate than dry products, but are still susceptible to antagonism from oil-based products and their specific HLB surfactant systems.

This is most likely to occur if the Flowable product is added to an emulsifiable concentrate or spray oil, inhibiting the dispersant and suspending agents from working effectively. It can also occur if the Flowable has been added to a minimal volume of water, followed by the emulsifiable concentrate. In this case the concentrate mix is more likely to be antagonised and destabilised.

Wettable Powders, Dry Flowables and Flowables have very low solubility in water, so they cause a minimal increase in the ionic strength of the water. This allows the suspension to remain stable and still provide capacity for emulsification of oil/hydrocarbon-based products. The emulsifiable concentrates can form stable emulsions in the available water, provided the final HLB of the surfactant mix and functional chemistry of the compounds are compatible.

SOLUBLE LIQUID CONCENTRATE

These products, e.g. Glyphosate CT, are the final product type to be added. The active is already dissolved in water and is therefore only diluted in the spray tank mix.

These products will increase the ionic strength of the water phase, but not usually enough to break or destabilise emulsions.

ADJUVANTS

Adjuvants, especially oil-based, are added last so that all other products have maximum chance of being fully dispersed/suspended or emulsified prior to this addition.

OVERCOMING POTENTIAL USE PROBLEMS

The most effective way of pre-screening mixes by conducting a jar test.

This test prevents a costly, time-consuming and environmentally unfavourable outcome. Manufacturer guidelines should be followed as they have the best knowledge of the performance and capabilities of their products and surfactant systems in use. Manufacturers can predict, with more certainty than anyone else, the potential for favourable or unfavourable outcomes.

CONDUCTING A JAR TEST

A jar test is easy. The two most important aspects are using the same ratios of products to water and the same mixing order as intended in the field.

A 1.25 L PET bottle is ideal for measuring, 100 mL marks can easily be drawn on the bottle.

In Australia, all horticultural label recommendations have a product volume per 100 L statement. Therefore, using 1 L as the jar test standard makes it easy. All product rates have to be divided by 100. For example, Nufarm Tri-Base Blue® with an intended user rate of 280 mL/100 L would be used in a jar test at 2.8 mL/L. Most adjuvants rates are expressed as product per 100 L as well. Small volume syringes can be obtained from pharmacies and chemist shops.

Measuring dry formulations is a bit more complicated. There are relatively inexpensive electronic scales that allow you to accurately measure, for example, 0.5 g. Good quality kitchen scales can also be used. They should be accurate to 20g. Weigh 20 g on a piece of paper and spread the volume out flat. Divide the product into two equal halves (= 10 g). Divide that into 5 lots (= 2g) and so on until the 0.5 g is reached. This is not super accurate - but for a jar test it is close enough. In mixtures problems are generally not caused by small volume but by the large volume products. Be aware that small volume products can be affected by the large volume products, for example SUs and pH changing chemistry.

When the first chemical is introduced, the tank would be 70% full. That can be replicated by using only 700 mL in the bottle to begin with. The rest of the water can be added at the end.

Shaking the bottle effectively mimics agitation. Dry formulations need a while to dissolve. Keep shaking! When all the mixed products are added, at the intended volume and the intended mixing order, the jar test should represent an accurate outcome of what to expect in the tank.

FORMULATIONS AND MIXING ORDER

INTERPRETATING A JAR TEST

The best outcome is a stable, homogeneous solution - this would be a very good indication that the tank mix can go ahead. If banding or layers of obviously different substances are visible, the solution is not stable. Good agitation may overcome the problem. After re-shaking, the solution should not form layers for 3 minutes. If layering recurs after 30 seconds, a mix should not be attempted. If a jar test produces sediment, a mix should not be attempted.

OVERCOMING PROBLEMS

If a jar test has a negative outcome, several attempts could be made to overcome the problem:

- Try more water. Instead of using 70%, use 100% of tank capacity when starting the mixing process
- Change water sources – instead of bore water use tap or rain water
- Swap brands. Better quality brands or different chemistry, for example different glyphosate salts
- Allow more time for dry formulations to dissolve, for example 10 minutes for dry ammonium sulphate

A jar test will only show up physical incompatibility, not biological efficacy/or crop safety.

DRY AMMONIUM SULPHATE

AMS is one of the most commonly used tank additives in Australia. It's quality - even within the same brand, varies considerably. It is ESSENTIAL to give the dry product sufficient time to dissolve (= 10 minutes) before the next product is introduced into the tank. It is also ESSENTIAL to have 70% of the tank filled before start mixing dry AMS. The other, easier option with no mixing requirements is to use liquid ammonium sulphate, such as Liase.

INVERT OR REVERSE EMULSIONS

When introducing high load Oil/Wetter combinations into the spray tank, following the correct procedure is important to prevent the possibility of a mayonnaise like thick white foam or cream forming that can cause problems in the tank mix.

This phenomenon is known as an invert or reverse emulsion it occurs if the initial contact of the oil and spray solution takes place in too low water volumes. Small amounts of water form emulsion droplets in the oil phase rather than small amounts of oil forming emulsion droplets in the water phase. Cold water can exacerbate the problem.

The key to preventing this occurring is to ensure that oils are not mixed in low water volumes. The risk arises when using Granni Pot or Suction Probe systems:

- When an induction system is used, the most reliable way to mix oil is to put only oil in the induction tank – do not pre-mix with water
- If a pre-mix with water is used in an induction system, the ratio of mixing must be at least 1 to 10 (oil to water)

MIXING ORDER

MIXING ORDER

1. Fill the spray tank to at least 70% full. Run agitation
2. Add a **water conditioner**
3. Add a **Water Dispersible Granule (WDG)** or **Water Soluble Granule (WSG)** Then allow at least 10 minutes for complete dispersion
4. Add a **Suspension Concentrate (SC)**
5. Add a **Emulsifiable Concentrate (EC)**
6. Add a **Soluble Liquid (SL)**
7. Fill the spray tank to nearly full
8. Add a **glyphosate (SL-G)**
9. Add an **adjuvant** and fill the tank

Figure 137

Unless sure, do not tank mix multiple products before checking compatibility charts/labels. Physical compatiblity does not guarantee biological compatibility. Do not tank mix with other products or trace elements without reference to a Nufarm representative.

CLEANING PROCEDURE

CHAPTER SUMMARY

- Aim to routinely clean at the end of each day
- Always clean filters and nozzle screens
- Consider having a separate (old or second hand) sprayer for high risk chemistry, e.g. sulfonylureas
- Know the contamination risk of the products sprayed and what cleaning agent to use for decontamination
- Always clean immediately after the use of high risk chemistry, e.g. sulfonylureas

Residues in spray equipment can cause serious crop injury. Good sprayer hygiene will not only minimise this risk but also increase the lifespan of equipment. Most herbicides can be sufficiently flushed out of the system with a triple rinse of water. Others, (e.g. sulfonylureas), have the potential to cause crop damage at minute traces – so they need to be removed completely. Different chemistry may require different cleaning agents (Figure 139). So, product knowledge is essential. Herbicides that have the potential to cause contamination problems will have a detailed cleaning procedure outlined on their label.

BOOM FLASH AT END OF SECTION

Figure 138

GENERAL CLEANING PROCEDURE

STEP 1: PRE-CLEAN

Drain the spray tank and lines thoroughly. Rinse the spray tanks, boom and hoses with clean water. Remove any visible deposits. Rinse all interior tank surfaces (e.g. lids and inner roof) for 10 minutes. Flush boom lines. Drain tank.

STEP 2: FIRST CLEAN

Fill the tank with clean water and, if required, with appropriate cleaning agent. Flush the cleaning solution through the line and nozzles for 5 minutes. If applicable, open up the blind end of boom line sections. Stop flushing and add enough water to completely fill the tank. Agitate the system for 15 minutes. Several hours' soaking may be of benefit. Flush the system again and drain tank completely.

STEP 3: NOZZLE AND FILTER CLEAN

Remove filters, strainers and nozzles and clean with cleaning detergent in separate bucket.

STEP 4: FINAL CLEAN

Repeat step 2.

STEP 5: RINSE

Always rinse the tank and flush the boom, nozzles and hoses with fresh water.

TROUBLESHOOTING

The most commonly encountered reasons for cleaning failure:

- Spray tank not filled up to the top
- Wrong cleaning agent
- Cleaning agent too old (e.g. chlorine)
- Residues in blind end of boom line not addressed (Figure 138)
- Filters and/or nozzle screens not cleaned
- Old equipment with poor hygiene history (cracks and scale build-up)

CLEANING PROCEDURE

HERBICIDES AND CLEANING PRODUCTS

GROUP	CHEMISTRY	PRODUCTS	CLEANING PRODUCT
A	Dims	Sequence®	Tank and Equipment Cleaner
	Fops	Exert® 520	
B	Imidazolinones	Sentry™, Kyte® 700 WG	Small amount of Tank and Equipment Cleaner or water
	Sulfonyl Ureas	Associate®, Lusta®, Olando®	Chlorine bleach
		Sempra®	
	Sulfonamides	Broadsword®	
C	Triazines	Atradex® WG, Nu-trazine 900 DF, Convoy® DF, Diuron 900DF	
		Flowable Diuron, Flowable Simazine	
		Prometryn 900 DF, Simazine	
	Benzonitriles	Bromicide® 200	
D	Dinitroanilines	TriflurX®, Rifle® 440	
F	Phenoxynicotinanilides	Minder®, Nugrex®	
G	Diphenyl ethers Triazolinones	Striker®, TERRAIN®, Nail™ 240 EC, Unity®	Alkaline detergent 'Omo®' or 'Spree®'
I	Benzoic Acids	Kamba® 500	Tank and Equipment Cleaner
	Phenoxy acetic acids		
	MCPA (amine)	Agritone® 750	Cloudy Ammonia followed by Tank and Equipment Cleaner#
	MCPA (ether)	LVE Agritone®, Broadside®, Bromicide® MA, Nugrex®	Tank and Equipment Cleaner
	MCPA (potassium salt)	Trooper® 242	
	2,4-DB	Buttress®	Cloudy Ammonia followed by Tank and Equipment Cleaner#
	2,4-D (dimethylamine and monoethylamine)	Amicide® Advance 700	
	2,4-D (dimethylamine)	Baton® Low, Kamba® M	
	2,4-D (ethylhexyl ester)	Estercide® Xtra 680	Tank and Equipment Cleaner
	Pyridines	Archer®, Comet® 400, Conqueror®, Invader® 600	
J	Thiocarbamates	Avadex® Xtra	Small amount of Tank and Equipment Cleaner or water
K	Chloroacetamides	Bouncer® 960 S	
L	Bipyridyls	Revolver®, Nuquat® 250	Water
M	Glyphosate	weedmaster® DST, weedmaster® DUO, weedmaster® ARGO, Credit®	
Q	Triazoles	Amitrole	Small amount of Tank and Equipment Cleaner or water
Z	Arylaminopropionic acids	Mataven® 90	

Figure 139

 # A first rinse with cloudy ammonia will clean hard deposits in filter and lines. After flushing the tank, a second rinse with Tank and Equipment Cleaner should be used as a follow up.

CHAPTER SUMMARY

- Spray when weeds are small using a water volume of (100 L/ha)
- Consider pre-emergent sprays
- 'Double-knock' is a very effective strategy for many difficult to kill weeds
- Reduce drift with a COARSE spray quality
- Consider the use of hooded sprayers
- Alternate the herbicide mode of actions
- Use robust rates

The set-up of nozzles to spray herbicides underneath trees and vines varies considerably. Generally, the more nozzles the better. The use of off-centre nozzles is common. Angle spraying (see page 13) is an advantage. Air induction nozzles are the nozzles of choice. Boomless nozzles are sometimes used but their coverage is not as uniform so water rates should be increased.For calibration purposes, w in the formula on page 50 becomes the width of the swath divided by the number of nozzles, e.g. 1.5 m swath width divided by 5 nozzles equals w = 0.3 m.

WATER VOLUME

In theory, there is no specific reason for water volumes to be considerably higher than in broadacre spraying. However, growers often let weeds grow too big. Raising the boom underneath trees or vines to optimize coverage becomes difficult. Growers often use extraordinary amounts of water, thereby diluting the herbicide concentration, are creating unnecessary run-off. This is counterproductive. High water rates also mean higher work rate.

Spraying weeds when small will help to reduce water volumes to around 100 L/ha. The use of pre-emergent herbicides will reduce the number of weeds and slow growth, which will also help to keep the water volume down.

It should be avoided to spray translocated herbicides, such as glyphosate, with water volumes above 150 L/ha.

Coverage sensitive herbicides such as paraquat may require higher water volumes in dense and tall weed situations but volumes above 300 L/ha should be avoided. In those situations a double-knock is often the better option.

For soil applied herbicides, higher water volumes will not help to flood product into the soil. Even a 1000 L/ha rate is only equivalent to 0.1 mm of rainfall. These products need irrigation, rainfall or physical incorporation.

CROPLANDS HERBILINER

Figure 140

DOUBLE-KNOCK

A double-knock strategy can be a very effective way to control difficult weeds. One spray of herbicide is followed a short while after with a second application of the same or different herbicide.

Translocated herbicides, such as glyphosate should be followed up with a desiccant 4 to 7 days later. The idea is to give the first product sufficient time to get to the target area in the plant then to burn of the green tissue to stop further energy production.

When a desiccant is followed by a second desiccant, the second spray should be 10–14 days afterwards. The idea is to burn off green tissues, give the plant sufficient time to mobilise and exhaust reserves, re-shoot then to hit it again.

DRIFT

Using herbicides underneath trees and vines can be dangerous to your own and other crops. Translocated herbicides represent a far greater risk to trees and vines than none translocated herbicides that produce only localized damage. When using knockdowns, it is advisable to use translocated products such as weedmaster Duo in dormant situations when there is no green tissue to take up the herbicide. Once green tissue is present, it is much safer to use non-translocated products such as Nufarm Nuquat®.

Products that can produce vapour drift, such as pendimethalin, should be used in dormant situations.

Using a COARSE spray quality will reduce the risk of drift. A FINE spray quality should be avoided. Water volumes are usually sufficiently high to achieve good coverage. Many manufacturers are offering hooded herbicide sprayers, such as the Croplands Herbiliner (Figure 140), especially designed for risk free spraying underneath tree and vine crops.

HERBICIDE RESISTANCE

The continuous use of the same group of herbicides will eventually result in weeds being resistant to that group. So it is essential to alternate one mode of action with another mode of action. Instead of using glyphosate year after year, it is advisable at least every third year, to introduce an application of, for example, a paraquat product such as Nufarm Nuquat®. Table 139 on page 84 gives examples of which herbicides belong to which mode of action group. Mixing herbicides with compatible modes of action in the same application is another way to prolong the lifespan of a herbicide.

Smaller areas give growers the opportunity to use modes of action and products that simply would be too expensive in broadacre situations, for example Nufarm Amitrole® T.

FORMULATIONS AND RATES

Some herbicide actives come in formulations especially suited for horticultural situations. For example weedmaster DUO is a glyphosate formulation with an aquatic friendly surfactant system. It is popular with council workers and in orchards because it provides more flexibility around water bodies such as creeks, ponds and dams. The label covers many horticultural and aquatic weeds not found on broadacre glyphosate products. Compared to broadacre, the areas sprayed with herbicides in orchards are relatively small. It becomes economical to consider using higher product rates. This makes efficacy more robust, and in many cases introduces or increases residual activity. For example, Nufarm Rifle® (pendimethalin) used under trees and vines in rates up to 9 L/ha provides long lasting pre-emergent control of a wide range of weeds. By contrast the broadacre use rate of around 2-3 L controls only a fraction of those weed species and provides only a fraction of the residual activity.

Higher rates are more expensive but it provides the grower with more robust kill, more flexibility and enriches the arsenal of herbicide tools.

COST EFFECTIVE WEED CONTROL IN VINEYARD

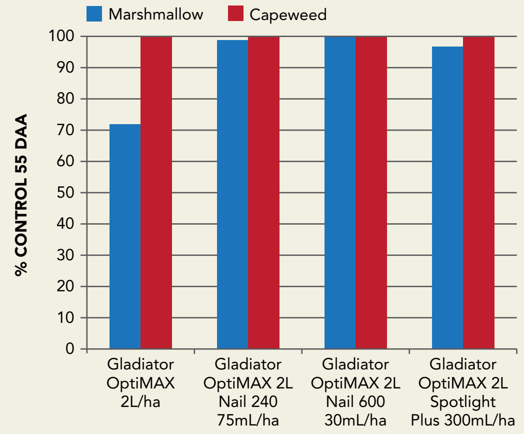


Figure 141
Source: Nufarm, 2013, Barossa Valley
Nail 240 and Nail 600 were used with Supercharge at 0.5% v/v

COST EFFECTIVE WEED CONTROL IN VINEYARD

Figure 142

BOOMSPRAY CALIBRATION

CHAPTER SUMMARY

Boom sprayers need to be correctly calibrated to deliver the desired amount of chemical onto the target. A poorly calibrated boom sprayer may result in:

- Increase in chemical costs
- Increase in crop effect
- Decrease in efficiency
- Potential loss in yield

Even a 10% change in flow rate can add up to large sums…

So it is advisable to calibrate the boom sprayer at least every 12 months. This is less complicated than you may think. The following procedure provides a practical on-farm guide.

Equipment needed:

- A watch, displaying seconds
- A jug, displaying a volume scale
- At least one new nozzle of the type fitted onto the boom
- Nozzle tip reference tables to determine flow rates and spray quality (available from Nufarm/Croplands)
- Calculator
- Nozzle cleaning brush
- Tape measure, or other device to measure a distance of 100 m

Before starting the calibration the spray equipment needs to be checked to eliminate basic faults:

- Nozzles – all fitted nozzles should be of the same type and size. Their spray pattern should be even (nozzles and strainers may need to be cleaned and replaced if necessary).
- Boom – hoses and joins should be checked for leaks. All systems should be in operating order.
- Tank – should be half filled with water.

The boom spray calibration is affected by two main factors:

A) Travel speed (Step 1) and
B) The output of nozzles (Step 2 – 5)

In the following procedure these two factors are checked independently, but ultimately, they are inseparably linked together.

STEP 1: SPEED CALIBRATION

100m

40 sec

To measure travel speed accurately travel over an exact distance (commonly 100 m) and measure the time it takes to travel that distance. Mark the precise distance with measuring tape and mark. Permanent markers make this measured stretch a handy tool for future use.

Undertake the calibration in the gear and RPM's the applications are commonly done with.

The tank should be half filled. Sufficient run up to ensure the starting line is crossed already travelling at desired speed.

Repeat the procedure at least twice to eliminate error. The travel speed in km/h can then be calculated from this simple formula:

km/h = Distance (m) x 3.6 / time (sec).

EXAMPLE

It took 40 sec (measured twice to be sure) to travel 100 m. The speed is 100 m x 3.6 / 40 sec = 9 km/h.

NOTES:

BOOMSPRAY CALIBRATION

STEP 2: CALCULATING OF NOZZLE FLOWRATE

At first it is necessary to work out what the nozzle output should be. The nozzles can then be checked to see if they are delivering the flow rate they are supposed to deliver. For this calculation three things need to be determined:

1. What is the preferred application speed (already measured)
2. What is the preferred water rate per ha
3. What is the nozzle spacing on the rig

Nozzle spacing

The most common spacing between nozzles on boom sprayers is 50 cm. It is important to be sure of the exact nozzle spacing. If in doubt, measuring is advisable. For banding situations see page 50.

EXAMPLE

The measurement was 50 cm.

Application Volume

The desired application volume in L/ha can be obtained from pesticide labels or other publications from manufacturers (e.g. Nufarm Boom Spray Application Guide).

EXAMPLE

The product used was weedmaster® Duo for control of capeweed and winter grass. The label advised that 75-200 L/ha was a sufficient water rate. 120 L/ha was chosen.

Calculation

A simple formula is transforming all this 'large scale' application information into a single, easy to measure 'output per nozzle per minute' figure.

$$\text{L/min/nozzle} = \frac{\text{L/ha x km/h x W (m)}}{600}$$

L/min/nozzle	= Nozzle flow rate in litre per minute
L/ha	= Water application rate per hectare
Km/h	= Driving speed
W	= Width of nozzle spacing in m
600	= Constant

EXAMPLE

The desired water rate was 120 L/ha, applied with a speed of 9 km/h and the boom had a nozzle spacing of 50 cm.

$$\text{L/min} = \frac{\text{120 L/ha x 9 km/h x 0.5 m}}{600} = \text{0.9 L/min}$$

To achieve this goal every single nozzle needs to deliver 0.9 L/min.

STEP 3: SELECTING PRESSURE AND SPRAY QUALITY

Nozzles deliver different flow rates and droplet sizes (commonly called spray quality) at different pressures.

The pressure needed to produce a certain flow rate for a specific nozzle type and size can be found in specific tables (Croplands Optima Catalogue, Nufarm Nozzle Charts, TeeJet® Catalogue).

For efficacy and legal reasons it is important to be clear about the spray quality a specific nozzle type is going to produce. If in doubt, an advisor should be consulted. For example, it is not desirable to calibrate and set up a nozzle type and size that can only spray FINE to MEDIUM spray quality when the chemical that is going to be used has to be sprayed with a COARSE to VERY COARSE spray quality. To minimise chemical loss through drift, it is advisable to choose a set up that produced the coarsest spray quality without compromising efficacy.

Desired spray quality information can be obtained from chemical labels or additional information from manufacturer (e.g. Nufarm Boom Spray Application Guide, Croplands Optima Catalogue).

EXAMPLE

To control capeweed and winter grass weedmaster® Duo was used, selecting a COARSE spray quality according to the Nufarm Boomspray application guide (see appendix).

The boom was fitted with agrotop AirMix® 015 nozzles.

According to the Nufarm Nozzle Chart reference, the pressure set-up needed to be around 4 bar to get the desired flow rate of 0.9 L/min. The Nufarm Nozzle Chart showed that around 4 bar this nozzle type and size is producing a COARSE spray quality. Therefore this nozzle type was suited for the planned application.
The boomsprayer needed to be set up to spray at 3.8 bar to deliver the desired flowrate and spray quality.

BOOMSPRAY CALIBRATION

STEP 4: PRESSURE SET-UP

All the theoretical work on nozzle flow rates is now finalised.

At least one old nozzle needs to be replaced with a new nozzle of the same type (the old nozzles may be worn). The sprayer can be turned on now and the desired pressure can be selected. If the pressure gauge is measuring the pressure at the nozzle end, measuring can start now.

However, many gauges are measuring the pressure at the pump end. In this case one nozzle needs to be replaced with a nozzle pressure Gauge (obtainable from Croplands) to measure the correct pressure at the nozzle end. As a rule of thumb, if the pressure between pump and nozzle end varies by more than 20% there is a serious pressure drop and the system should be checked.

The tank should be filled with water only since all table values are based on water.

STEP 5: MEASURING NOZZLE FLOW RATE

Place a jug underneath the new nozzle to collect fluid for 60 seconds. This is measuring the output per nozzle per minute.

If the output is too much for the scale of the jug, the time may be halved to 30 seconds. In this case the measured volume needs to be doubled to refer back to a per minute output. The measured volume can now be compared to the theoretical value calculated above.

Depending on the difference, the pressure may need some fine-tuning to obtain exactly matching flow rate values.

Individual nozzle outputs may vary. So repeat measurements with a minimum of three nozzles per boom section to check for nozzle wear. All outputs should be within a 10% range. If more than one nozzle is out of range, replace the whole nozzle set.

EXAMPLE

An old agrotop AirMix 015 was replaced with a new one. The pressure was set at 3.8 bar at the nozzle end. The measured flow rate of the new nozzle was 0.85 L/min. Therefore the pressure needed to be slightly increased to 4 bar and the flow rate was brought up to the desired 0.9 L/min for the new nozzle.

The boom had 5 sections and therefore measurements needed to be repeated for three nozzles in each section. Results were:

0.85	0.85	0.85	0.85	1.0
0.85	1.0	0.85	0.85	0.85
0.85	0.85	0.85	1.0	0.85

Three of the nozzles had a flow rate differing by around 10% from the desired output. A re-check of those three nozzles gave the same result. Therefore, there was little confidence in the future performance of the whole set. The two-year-old set needed to be replaced.

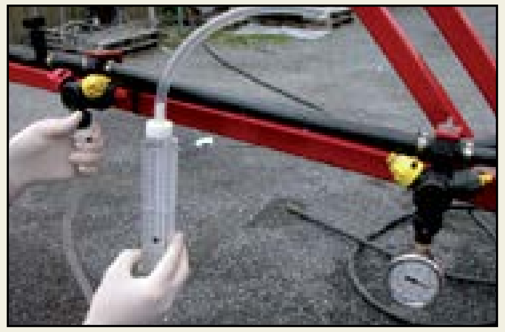
After replacement, the new nozzles were checked again and flow rates were uniform at 0.9 L/min.

STEP 5B: ALTERNATIVE MEASURING OF NOZZLE FLOW RATE

Rather than using a jug and timer, an instant Tip Tester can be used. This method is not as accurate, but handy for doing a quick check to compare many nozzles in a short space of time.

The Tip tester has a rubber seal that is placed tightly over the nozzle. The actual flowrate coming out of the nozzle pushes up a little ball in a tube.

By looking at the position of the ball the flow rate can be read directly from a scale (see picture).



BOOMSPRAY CALIBRATION

STEP 6: AUTOMATIC RATE CONTROLLER

Many boom sprayers are set up with automatic rate controllers that will allow a constant per ha output with varying speeds, by adjusting the flow rate.

The two main factors governing the system are again the precise measuring of:

A) Speed

B) Flow rate

At the initial set-up of the machinery, precise inputs into the rate controller would have assured precise operation.

However over time, the machinery will wear so it is important to check if initial inputs are still calibrated.

Flowmeter

The greater the water volume measured, the more precise the outcome. It is not practical to obtain overall boom flow rates through nozzles. Therefore the easiest way is to take off a section of boom hose (all other sections need to be closed) and to fill a measuring drum up to the 100 L mark. The 100 L volume can then be compared to the volume measured by the flowmeter. If necessary, controller inputs need to be adjusted (refer to individual controller handbooks).

Speed

The procedure to reset the rate controller will be different from system to system but it will be the same in principal. An exactly measured 100 m distance (see Step 1) needs to be travelled and compared to the distance calculated by the rate controller. If necessary change the controller inputs (refer to controller handbook).

CALIBRATION OF TREE AND VINE SPRAYERS

In principle, there are no major differences in calibrating a tree and vine sprayer or a boom sprayer. However, it is much more difficult to measure individual nozzle outputs because they don't point downwards and often are high up.

Speed

Again, speed is a critical factor. It can be measured and calibrated exactly with the same procedure as it was described for boom sprayers.

Overall flow rate

A good way to check the overall flow rate is to fill the tank up to the rim until the first water is running out through the top. This is a very precise point for repetition. Now the sprayer can be operated at the desired pressure for a minute. Measure the amount of water it takes to come back to the point when the water starts to run over the rim. The refill volume should be close to the theoretical output per minute volume. See page 52-54 for a method to work out the L/min rate.

Single nozzle flow rate

In dilute spraying, measuring individual nozzle outputs is not that important if sets are regularly replaced. More important is to check for coverage (see page 42). In concentrate spraying the margin for error becomes smaller and nozzles must be replaced regularly or at least checked once a year. You will need some form of tube that guides the water from the nozzle tip to the sample container. The simplest form could be a large, robust rubbish bag. A small hole in the closed end is pulled and closely tied (e.g. rubber band) over the nozzle body, and the open end placed in a bucket at the point of measuring. The measuring procedure is the same as with boom sprayers. Another option, especially for high up nozzles in tower sprayers, is to remove nozzles and fit them on to a boom sprayer for testing. The boom sprayer needs to be able to produce a minimum of 5 bar. For nozzle outputs see page 49.

RECORD KEEPING

CHAPTER SUMMARY

Keeping detailed records is essential for:

- Investigating of product performance
- Drift liability
- QAS and APVMA requirements
- Paddock and orchard history

GENERAL

In March 2010 the APVMA issued new legislation in relation to spray drift management. Under these new label directives, users of agrochemicals MUST make an accurate written record of the details of each spray application within 24 hours following application and keep this record for a minimum of two years.

The spray application details that MUST be recorded are:

- Date of application with start and finish times
- Location address and paddock/s sprayed
- Full name of product/s used
- Amount of product/s used per hectare and number of hectares applied to
- Crop situation and weed/s or pest/s
- Wind speed and direction during application
- Air temperature and relative humidity during application
- Nozzle name (brand, type, spray angle, capacity) (e.g. TeeJet® AI 11002) and spray system pressure measured during application
- Name and address of person applying this product

While not implemented on all labels yet, it includes where the industry is heading and should be adopted immediately. Read the label.

Record keeping is not only a legal requirement, it is a fundamental part of best management practice in the field. Detailed records are vital in the investigation of product performance.

Liability is an ever increasing issue for the farming society. Keeping records provides some form of quality assurance and defence. Having no or only poor records increases the risk of being blamed for adverse incident in the neighbourhood.

Keeping records is essential for:

- Investigating of product performance - (e.g. weather conditions, product used, rates, mixing order and volumes)
- Drift liability - (e.g. Sprayer set-up, weather conditions, products used)
- QA Paddock and orchard history - (e.g. rotation, disease, use of soil residuals, resistance management)

TRACTOR-MOUNTED MOBILE WEATHER STATION

Weather data can be measured and recorded with simple handheld equipment before and after the application (see page 63). A more advanced option is a tractor-mounted mobile weather stations such as the Watchdog. Weather conditions can change rapidly and the ability to monitor data on the go enables applicators to make informed decisions. Tractor-mounted mobile weather stations close the loop between sophisticated pre-application planning and final execution. They are perfect partners for Spraywise® Decisions.

Tractor-mounted weather stations are becoming more common place. For example, Croplands provides the ultrasonic Watchdog as a standard for their Rogator range.

Watchdog measures air temperature, humidity, dew point, wind chill, barometric pressure and apparent wind speed and direction. The user can use the snapshot button to capture current conditions.

Considering the price of modern spray equipment the addition of a tractor-mounted weather station is extraordinary value for money.

SPRAYWISE DECISIONS APPLICATION WINDOWS

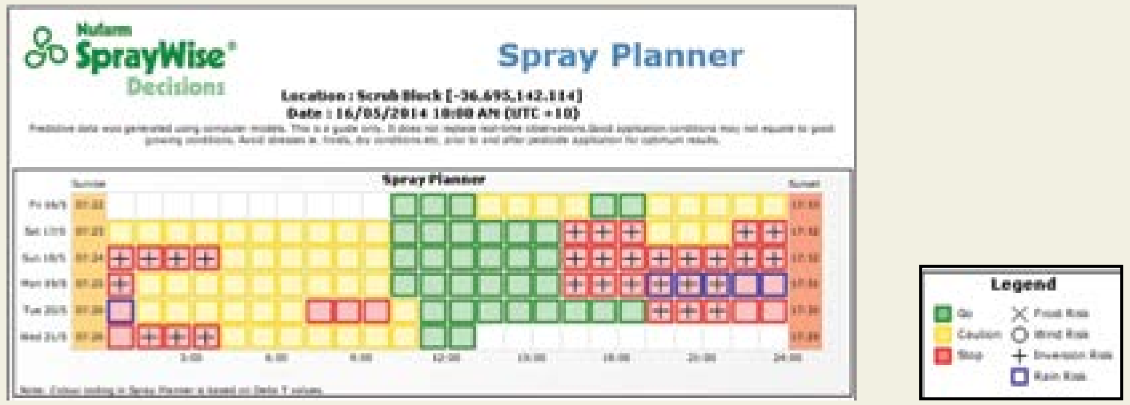


Figure 143

SPRAYWISE DECISIONS

Spraywise Decisions is an advanced online application decision-making support tool. This exciting website can predict the weather on your property for up to 14 days in advance. The online system has the unique capacity to produce property specific meteograms to any 1 square km grid across Australia. This technology effectively develops a virtual weather station in your own backyard.

HOW DOES IT WORK?

Computer models take Bureau of Meteorology data from 250 sites across Australia and run it through a series of mathematical algorithms. These algorithms then utilise topographic information to transform the general information into a detailed 1 square kilometre grid forecast across Australia. The user then has the ability to place a reference point on a detailed map. This reference point is utilised to provide the forecast for the selected point. Spraywise Decisions provides individual forecasts for these selected points.

WHAT DOES IT OFFER?

Spraywise Decisions offers a range of forecast information provided as meteograms. These include:

- Rainfall
- Delta T
- Wind speed and direction
- Temperature
- Relative humidity %
- Evapotranspiration
- Sunrise and sunset times
- Flexible Delta T table with the option for coarse or greater, or medium or finer spray quality

SELECTION OF SPRAYWISE DECISIONS METEOGRAMS

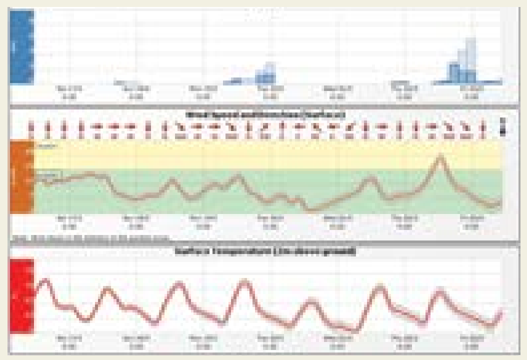


Figure 144

This forecast is then summarised in a 5 day spray planner. The planner contains additional predictions such as:

- Inversion risks
- Frost periods

Spraywise Decisions is a subscription based web service that can be utilised by all persons involved in the decision making process around chemical application (e.g. farmers, spray contractors, advisers). The information provided is a forecast only. It does not replace actual weather conditions at the site of application. Weather conditions at the site of application still need to be taken into consideration prior to commencing the application.

The website is located at: www.spraywisedecisions.com.au.

The web-site can also be accessed by a web-enabled mobile phone which is particularly useful when in the field assessing upcoming weather conditions.

BROADCAST AND TURF APPLICATIONS

L/HA 50 CM NOZZLE SPACING

NOTE: COLOUR CODING FOR NOZZLE SIZES ARE NOT RELATED TO COLOUR CODING FOR SPRAY QUALITIES

Nozzle	Bar	Flowrate	6 km/h	8 km/h	10 km/h	12 km/h	14 km/h	15 km/h	16 km/h	17 km/h	18 km/h	20 km/h	22 km/h	24 km/h	25 km/h	26 km/h	28 km/h	30 km/h
01 Orange	2	0.33	66	49	39	33	28	26	25	23	22	20	18	16	16	15	14	13
	3	0.4	80	60	48	40	34	32	30	28	27	24	22	20	19	18	17	16
	4	0.46	92	69	55	46	40	37	35	32	31	28	25	23	22	21	20	18
	5	0.52	104	78	62	52	44	41	39	36	35	31	28	26	25	24	22	21
	6	0.57	114	85	68	57	49	45	43	40	38	34	31	28	27	26	25	23
	7	0.61	122	92	73	61	52	49	46	43	41	37	33	31	29	28	26	24
	8	0.65	130	98	78	65	56	52	49	46	43	39	35	33	31	30	28	26
	9	0.69	138	104	83	69	59	55	52	49	46	42	38	35	33	32	30	28
	10	0.73	146	110	88	73	63	59	55	52	49	44	40	37	35	34	32	29
015 Green	2	0.49	98	74	59	49	42	39	37	35	33	30	27	25	24	23	21	20
	3	0.6	120	90	72	60	51	48	45	42	40	36	33	30	29	28	26	24
	4	0.69	138	104	83	69	59	55	52	49	46	42	38	35	33	32	30	28
	5	0.78	156	116	93	78	66	62	58	55	52	47	42	39	37	36	33	31
	6	0.85	170	127	102	85	73	68	64	60	57	51	46	42	41	39	37	34
	7	0.92	184	138	110	92	79	73	69	65	61	55	50	46	44	42	40	37
	8	0.98	196	147	118	98	84	79	74	69	65	59	54	49	47	45	42	39
	9	1.04	208	156	125	104	89	83	78	74	69	63	57	52	50	48	45	42
	10	1.1	220	164	131	110	94	87	82	77	73	66	60	55	52	50	47	44
02 Yellow	2	0.65	130	98	78	65	56	52	49	46	43	39	35	33	31	30	28	26
	3	0.8	160	120	96	80	69	64	60	56	53	48	44	40	38	37	35	32
	4	0.92	184	139	111	92	79	74	70	65	61	56	50	46	44	43	40	37
	5	1.03	206	155	124	103	89	83	78	73	69	62	56	52	50	48	45	41
	6	1.13	226	170	136	113	97	91	85	80	75	68	62	57	54	52	49	45
	7	1.22	244	183	147	122	105	98	92	86	81	74	67	61	59	57	53	49
	8	1.31	262	196	157	131	112	105	98	92	87	79	71	65	63	60	56	52
	9	1.39	278	208	166	139	119	111	104	98	93	83	75	69	66	64	60	55
	10	1.46	292	219	175	146	125	117	110	103	97	88	80	73	70	67	63	58
025 Lilac	2	0.82	164	122	98	82	70	65	61	58	55	49	45	41	39	38	35	33
	3	1	200	150	120	100	86	80	75	71	67	60	55	50	48	46	43	40
	4	1.15	230	173	138	115	99	92	87	81	77	69	63	58	55	53	50	46
	5	1.29	258	194	155	129	111	103	97	91	86	78	70	65	62	60	56	52
	6	1.41	282	212	170	141	121	113	106	100	94	85	77	71	68	65	61	57
	7	1.53	306	229	183	153	131	122	115	108	102	92	83	76	73	70	66	61
	8	1.63	326	245	196	163	140	131	123	115	109	98	89	82	78	75	70	65
	9	1.73	346	260	208	173	148	139	130	122	115	104	95	87	83	80	74	69
	10	1.83	366	274	219	183	157	146	137	129	122	110	100	91	88	84	79	73
03 Blue	2	0.98	196	147	118	98	84	79	74	69	65	59	54	49	47	45	42	39
	3	1.2	240	180	144	120	103	96	90	85	80	72	65	60	58	55	52	48
	4	1.39	278	208	166	139	119	111	104	98	93	83	75	69	66	64	60	55
	5	1.55	310	232	186	155	133	124	116	109	103	93	85	77	74	72	67	62
	6	1.7	340	255	204	170	145	136	128	120	113	102	93	85	82	78	73	68
	7	1.83	366	275	220	183	157	147	138	129	122	110	100	92	88	85	79	73
	8	1.96	392	294	235	196	168	157	147	138	131	118	107	98	94	90	84	78
	9	2.08	416	312	249	208	178	166	156	146	139	125	113	104	100	96	89	83
	10	2.19	438	329	263	219	188	175	165	155	146	132	120	110	105	101	94	88
04 Red	2	1.31	262	196	157	131	112	105	98	92	87	79	71	65	63	60	56	52
	3	1.6	320	240	192	160	137	128	120	113	107	96	87	80	77	74	69	64
	4	1.85	370	277	222	185	158	148	139	131	123	111	101	92	89	85	79	74
	5	2.07	414	310	248	207	177	165	155	146	138	124	113	103	99	95	89	83
	6	2.26	452	339	272	226	194	181	170	160	151	136	124	113	109	105	97	91
	7	2.44	488	367	293	244	209	195	184	172	163	147	133	122	117	113	105	98
	8	2.61	522	392	313	261	224	209	196	184	174	157	142	131	125	120	112	104
	9	2.77	554	416	333	277	238	222	208	196	185	167	151	139	133	128	119	111
	10	2.92	584	438	351	292	250	234	219	206	195	176	160	146	140	135	125	117

Nozzle spacing	25 cm spacing	30 cm spacing	35 cm spacing	40 cm spacing	45 cm spacing
Conversion factor	2	1.66	1.43	1.25	1.11

This 50 cm nozzle spacing table can still be used for booms with different nozzle spacing by using the above conversion factors. **For example,** if pressure and speed are given, the L/ha value for 30 cm spacing can be calculated by multiplying the given L/ha table value by 1.66. And the other way around. **For example,** a grower wants to use 80 L/ha. His boom nozzle spacing is 30 cm. To use this table he needs to divide 80 L/ha by the 30 cm conversion factor (= 1.66). 80 L/ha / 1.66 = 48.2 L/ha = a 48.2 L/ha value in this 50 cm spacing table reflects a 80 L/ha value for 30 cm spacing.

Flow Rate

L/min/nozzle = $\frac{\text{L/ha} \times \text{km/h} \times \text{W(m)}}{600}$

Example

A Farmer wants to spray **70 L/ha**, drive with a speed of **18 km/h** and his boom has a nozzle spacing of **50 cm:**

70 L/ha x 18 km/h x 0.5 m ÷ 600 = 1.05 L/min

To do so he needs to use a nozzle that delivers **1.05 L/min**. He has several options, for example, he could use an **025 nozzle size at 3.5 bar or an 02 size at 5.5 bar** (see table).

L/min/nozzle	= nozzle flow rate in litre per minute
L/ha	= water application rate per hectare
Km/h	= driving speed
W	= Width of nozzle spacing in m
600	= constant

Travel Speed

Speed (km/h) = $\frac{\textbf{Distance (m) x 3.6}}{\textbf{Time (sec)}}$

For accurate application it is important to calibrate the speed of the tractor. An easy way to do so is to drive in the gear the application will be done in, measure the time it takes to travel **100 m** and apply this simple formula. For example, it takes the farmer **20 sec** to drive **100 m**. His application speed is **18 km/h**.

100m x 3.6 ÷ 20 seconds = 18 km/h

Application Rate

Application rate (L/ha) = $\frac{\textbf{L/min/nozzle x 600}}{\textbf{km/h x W}}$

Spot/Band Spraying

For spot and band spraying, the same formula can be used but W (nozzle spacing) becomes the spray width divided by the number of directed nozzles.

For example: a grower directs **3 nozzles** over a **1 m** strip.

W = 1 m ÷ 3 nozzles = 0.33 m

Pressure

1 bar (bar)
= 100 kilopascal (kPa)
= 14.5 pound per square inch (PSI)

1 pound per square inch (PSI)
= 6.89 kilopascal (kPa)
= 0.0689 bar (bar)

As a rule of thumb, to double the flow through a nozzle, the pressure must be increased four times.

APPENDIX

SPRAY QUALITY

Nozzle selection is often based upon droplet size. The droplet size from a nozzle becomes very important when the efficacy of a particular crop chemical is dependent on coverage, or the prevention of spray leaving the target area is a priority.

VF	F	M	C	VC	XC
VERY FINE	FINE	MEDIUM	COARSE	VERY COARSE	EXTREMELY COARSE

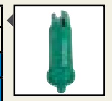
NOTE: COLOUR CODING FOR SPRAY QUALITIES ARE NOT RELATED TO COLOUR CODING FOR NOZZLE SIZES

Spray quality classifications are based on BCPC specifications and are in accordance with ASAE Standard S-572 at the date of printing. Classifications are subject to change.

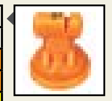
An important point to remember when choosing a spray nozzle that produces a droplet spectra in one of the six categories, is that one nozzle can produce different droplet spectra classifications at different pressures. A nozzle might produce MEDIUM droplets at low pressures, while producing FINE droplets as pressure is increased. Note: Always double check your application rates.

XR & XRC TeeJet®	Bar				
	1.5	2	2.5	3	3.5
XR	F	F	F	F	VF
XR110015	F	F	F	F	F
XR11002	F	F	F	F	F
XR110025	F	F	F	F	F
XR11003	M	F	F	F	F
XR11004	M	M	M	M	M

AI & AIC TeeJet®	Bar							
	4	4.5	5	5.5	6	6.5	7	8
AI110015	C	C	C	C	C	C	C	C
AI11002	VC	C	C	C	C	C	C	C
AI110025	VC	VC	VC	C	C	C	C	C
AI11003	VC	VC	VC	VC	C	C	C	C
AI11004	VC	VC	VC	VC	VC	C	C	C



Turbo TeeJet®	Bar							
	1.5	2	2.5	3	3.5	4	4.5	5
TT11001	M	M	M	F	F	F	F	F
TT110015	C	M	M	M	M	M	F	F
TT11002	C	C	M	M	M	M	M	M
TT110025	C	C	C	M	M	M	M	M
TT11003	C	C	C	C	M	M	M	M
TT11004	C	C	C	C	C	C	M	M



HARDI ISO F-110-	Bar				
	1.5	2	2.5	3	4
F-110-01	F	F	F	F	F
F-110-015	M	F	F	F	F
F-110-02	M	M	F	F	F
F-110-025	M	M	M	M	F
F-110-03	M	M	M	M	M
F-110-04	M	M	M	M	M

HARDI ISO LD-110-	Bar					
	1.5	2	2.5	3	4	5
LD-110-01	M	M	M	M	M	F
LD-110-015	M	M	M	M	M	M
LD-110-02	M	M	M	M	M	M
LD-110-025	C	C	M	M	M	M
LD-110-03	C	C	C	C	M	M
LD-110-04	C	C	C	C	C	M

DG TeeJet®	Bar				
	2	2.5	3	3.5	4
DG110015	M	F	F	F	F
DG11002	M	M	M	M	M
DG11003	C	M	M	M	M
DG11004	C	C	M	M	M

HARDI INJET	Bar					
	3	4	5	6	7	8
INJET-01	VC	VC	VC	C	C	C
INJET-015	VC	VC	VC	VC	VC	C
INJET-02	VC	VC	VC	VC	VC	VC
INJET-025	VC	VC	VC	VC	VC	VC
INJET-04	VC	VC	VC	VC	VC	VC

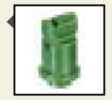
HARDI ISO MINIDRIFT	Bar					
	1.5	2	2.5	3	4	5
MINIDRIFT-015	C	C	C	C	M	M
MINIDRIFT-02	VC	C	C	C	C	M
MINIDRIFT-025	VC	VC	C	C	C	M
MINIDRIFT-03	VC	VC	VC	C	C	C
MINIDRIFT-04	VC	VC	VC	VC	C	C

agrotop AirMix® Flat Fan	Bar								
	2	2.5	3	3.5	4	4.5	5	5.5	6
AM11001	M	M	M	M	F	F	F	F	F
AM110015	XC	VC	C	C	C	C	C	C	M
AM11002	C	C	C	C	M	M	M	M	M
AM110025	VC	C	C	C	C	C	M	M	M
AM11003	VC	VC	C	C	C	C	C	C	M
AM11004	VC	VC	C	C	C	M	M	M	M

agrotop TurboDrop® TD	Bar								
	4	4.5	5	5.5	6	6.5	7	7.5	8
TD 110 015	C	C	C	C	C	C	C	C	C
TD 110 02	C	C	C	C	C	C	C	C	C
TD 110 025	VC	VC	VC	VC	VC	VC	VC	VC	VC
TD 110 03	VC	C	C	C	C	C	C	C	C
TD 110 04	VC	VC	VC	VC	VC	VC	C	C	C

Nufarm data supported by agrotop. This information supersedes data on previous versions distributed; Data for AM11004 - agrotop

TTI TeeJet®	Bar		
	1	to	7
TTI 110015	XC	XC	XC
TTI 11002	XC	XC	XC
TTI 110025	XC	XC	XC
TTI 11003	XC	XC	XC
TTI 11004	XC	XC	XC



APPENDIX

Nufarm SprayWise® BOOM SPRAY APPLICATION GUIDE

HERBICIDES		RECOMMENDED SPRAY QUALITY	PREFERRED WATER VOL. (L/HA)	LIASE	CHEMWET 1000	ACTIVATOR®	BONZA®	BANJO®	LI 700®	PULSE®
Agritone 750	SL	MEDIUM–COARSE	50-100							
Amicide Advance 700 (preparatory for cropping)	SL	COARSE-VERY COARSE	50 - 70							
Amicide Advance 700 (in crop)	SL	COARSE-VERY COARSE	50-70							
Amicide Advance 700 (optical spot spraying)	SL	COARSE-VERY COARSE	100							
Amitrole T	SL	MEDIUM–COARSE	MIN. 100							
Amitrole T (optional spot spraying)	SL	MEDIUM–COARSE	100							
Archer	SL	MEDIUM–COARSE	70-100							Woody Weeds
Archer 750	WDG	COARSE	50 - 100							
Associate	WDG	MEDIUM–COARSE	70-100							Woody Weeds
Avadex Xtra (clean bed)	EC	COARSE	50-70							
Avadex Xtra (stubbles)	EC	COARSE–VERY COARSE	70-100							
Baton Low	WDG	MEDIUM–COARSE	70-100							
Bouncer 960S	EC	COARSE	50-70							
Broadside	EC	COARSE#	70-100							
Bromicide 200	EC	COARSE#	70-100							
Bromicide MA	EC	COARSE#	70-100							
Buttress	SL	COARSE–VERY COARSE	110-200						*	
Comet 400 (in crop)	EC	MEDIUM–COARSE	70-100							
Comet 400 (non-crop)	EC	MEDIUM–COARSE	100							
Comet 400 (optical spot spraying)	EC	MEDIUM–COARSE	100							
Conqueror 400	EC	MEDIUM–COARSE	50							
Convoy DF	WDG	MEDIUM–COARSE	100-200	Compatibility						
Credit (broadleaf weeds)	SL-G	MEDIUM–COARSE	50	Always use with Bonus						
Credit (small grasses)	SL-G	MEDIUM#	70-100							
Credit (summer weeds)	SL-G	MEDIUM–COARSE	40-70							
Diuron 900DF (in crop)	WDG	MEDIUM–COARSE	50	Compatibility						
Diuron 900DF (non-crop)	WDG	MEDIUM–COARSE		Compatibility						
Estercide 800 (WA only)	EC	COARSE–VERY COARSE	50-70							
Estercide Xtra 680	EC	COARSE–VERY COARSE	50-70							
Glyphosate CT (broadleaf weeds)	SL-G	MEDIUM–COARSE	50							
Glyphosate CT (small grasses)	SL-G	MEDIUM#	70-100							
Glyphosate CT (summer weeds)	SL-G	MEDIUM–COARSE#	40-70							
Invader 600 (in fallow)	EC	MEDIUM–COARSE	50-70				Melons	Melons	Glyphosate CT	
Invader 600 (in sorghum)	EC	MEDIUM–COARSE	50-70							
Kamba 500	SL	MEDIUM–COARSE	50-70							
Kamba M	SL	MEDIUM–COARSE	50-70							
Kyte 700WG (pre-emergent)	WDG	MEDIUM–COARSE	50-70							
Kyte (post-emergent)	WDG	MEDIUM	70-100							
Lusta® (pre-emergence)	WDG	COARSE	50-70							
Lusta (post-emergence)	WDG	MEDIUM	70-100							
LVE Agritone	EC	MEDIUM–COARSE	50-70							
Nugrex	EC	MEDIUM#	70-100							
Nuquat 250	SL	MEDIUM#	70-100							
Nuquat 250 (optical spot spraying)	SL	MEDIUM	100							
Olando	WDG	MEDIUM	50 - 70							
Paragon®	EC	MEDIUM#	70-100							
Prometryn 900DF (bare soil)	WDG	MEDIUM–COARSE	50	Compatibility						
Prometryn 900DF (cotton, post-emergence)	WDG	MEDIUM–COARSE	70-100	Compatibility						
Ramrod® Flowable	SC	MEDIUM–COARSE	MIN. 200							
Revolver	SL	MEDIUM#	50-100		Silvergrass	Silvergrass				
Rifle®440 (stubble-free)	EC	COARSE	50-70							
Rifle 440 (stubble)	EC	COARSE–VERY COARSE	70-100							
Sempra®	WDG	MEDIUM–COARSE	80-150							
Sequence®	EC	MEDIUM#	70-100	Bicarbonates						
Simazine 900 DF (bare soil)	WDG	MEDIUM–COARSE	50							
Simazine 900 DF (pasture)	WDG	MEDIUM–COARSE	50-70							
Striker® (spike)	EC	MEDIUM–COARSE	50-70							
Striker (horticulture, residual control)	EC	MEDIUM–COARSE								
Terbazine 875 WG	WDG	COARSE –VERY COARSE	50-100							
TERRAIN	WDG	COARSE-VERY COARSE	80-100							

#These products may be sprayed with a COARSE spray quality only if used with agrotop AirMix or AI TeeJet® nozzles and using the higher end of preferred water volumes.*Do not mix Buttress with Liase® and LI 700® together.

WDG	Water Dispersible Granule (or Dry Flowable)	SC	Suspension Concentrate	EC	Emulsifiable Concentrate	SL	Soluble Liquid	SL-G	Soluble Liquid Glyphosate products

APPENDIX

Nufarm SprayWise® BOOM SPRAY APPLICATION GUIDE

HERBICIDES		RECOMMENDED SPRAY QUALITY	PREFERRED WATER VOL. (L/HA)	LIASE	CHEM-WET 1000	ACTIVA-TOR	BONZA	BANJO®	LI 700®	PULSE
TriflurX® (clean bed)	EC	COARSE	50-70							
TriflurX (stubbles)	EC	COARSE–VERY COARSE	70-100							
Trooper® 242	SL	MEDIUM–COARSE	50-70							
Trooper® 75D	SL	COARSE–VERY COARSE	50-70							
weedmaster ARGO® general	SL-G	COARSE-VERY COARSE	80 Max.							
weedmaster ARGO (broadleaf weeds)	SL-G	COARSE	50							
weedmaster ARGO (small grasses)	SL-G	MEDIUM-COARSE	70-100							
weedmaster ARGO (ARG, silver grass in spring)	SL-G	MEDIUM-COARSE	70-100		Use Wetter TX					
weedmaster ARGO (summer weeds)	SL-G	COARSE-VERY COARSE	40-70							
weedmaster ARGO (woody weeds)	SL-G	COARSE-VERY COARSE	Min. 100							
weedmaster DUO	SL-G	MEDIUM–COARSE	MIN. 100							
weedmaster DUO (woody weeds)	SL-G	MEDIUM–COARSE	MIN. 100							
weedmaster DUO (aquatic)	SL-G	MEDIUM–COARSE	MIN. 100							
weedmaster DST general	SL-G	COARSE-VERY COARSE	80 Max.							
weedmaster DST (broadleaf weeds)	SL-G	COARSE	50							
weedmaster DST (small grasses)	SL-G	MEDIUM-COARSE	70-100							
weedmaster DST (ARG, silver grass in spring)	SL-G	MEDIUM-COARSE	70-100		Use Wetter TX					
weedmaster DST (summer weeds)	SL-G	COARSE-VERY COARSE	40-70							
weedmaster DST (woody weeds)	SL-G	COARSE-VERY COARSE	Min. 100							

INSECTICIDES	RECOMMENDED SPRAY QUALITY	PREFERRED WATER VOL. (L/ha)	LI700®
Astound® Duo, bare earth	MEDIUM-COARSE	70	
Astound Duo, pasture, in crop	MEDIUM	70-100	
Chlorpyrifos 500EC	MEDIUM	70-100	
Dimethoate 400	MEDIUM	min. 50	
Fenitrothion 1000	MEDIUM	70-100	
Lepidex 500	MEDIUM	min. 100	

FUNGICIDES AND PGRs	CHEMWET 1000	ACTIVATOR	BOND®	LI700	PULSE
Champ Dry Prill					
Hornet® 430					Cereals
Penncozeb® 420SC					
Penncozeb 750DF					
Throttle® 500					Cereals
Tri-Base Blue®					
Unite® 720					

RECOMMENDED SPRAY QUALITY FOR FUNGICIDES AND PGRS IS MEDIUM. WATER RATES SHOULD BE KEPT UP TO ASSURE GOOD COVERAGE.
Spray quality classifications are based on BCPC specifications and are in accordance with ASAE standard S-572 at the date of printing. Classifications are subject to change.

HOW TO INTERPRET THE ADJUVANT TABLES

To minimise off-target drift use the higher recommended spray quality.

Products that benefit from the addition of an adjuvant have coloured boxes. A very specific fit is spelled out in the box, for example 'woody weeds' in the Pulse column. No fill means that adjuvants have shown little or no advantage when used with these pesticides or have not yet been tested.

Adjuvants can help to overcome the shortcoming of pesticide formulations in many circumstances. Recommendations are general guidelines only – always refer to the product label.

Green boxes indicate the adjuvants that offer the most benefits.

Yellow boxes indicate benefits but not as consistent.

NUFARM NOZZLE RECOMMENDATION TO PRODUCE A COARSE SPRAY QUALITY

Agrotop AirMix® Nozzles (Low Pressure 3-5 bar)

Travel Speed	Water Rate per ha: 40 L	50 L	60 L	70 L	80 L	100 L
10 km/h				AM 015	AM 015	AM 02
12 km/h			AM 015	AM 02	AM 02	AM 025
14 km/h		AM 015	AM 015	AM 02	AM 025	AM 025
15 km/h		AM 015	AM 015	AM 02	AM 025	AM 03
16 km/h		AM 015	AM 02	AM 02	AM 025	AM 03
17 km/h		AM 015	AM 02	AM 025	AM 025	AM 03
18 km/h	AM 015	AM 015	AM 02	AM 025	AM 025	AM 03
19 km/h	AM 015	AM 02	AM 025	AM 025	AM 03	
20 km/h	AM 015	AM 02	AM 025	AM 025	AM 03	
22 km/h	AM 015	AM 025	AM 025	AM 03	AM 03	
25 km/h	AM 02	AM 025	AM 03	AM 03		
28 km/h	AM 025	AM 025	AM 03			
30 km/h	AM 025	AM 03	AM 03			

TeeJet® AI Nozzles (High Pressure 5-8 bar)

Travel Speed	Water Rate per ha: 40 L	50 L	60 L	70 L	80 L	100 L
10 km/h						AI 015
12 km/h					AI 015	AI 015
14 km/h				AI 015	AI 015	AI 02
15 km/h			AI 015	AI 015	AI 02	AI 02
16 km/h			AI 015	AI 015	AI 02	AI 025
17 km/h			AI 015	AI 015	AI 02	AI 025
18 km/h		AI 015	AI 015	AI 02	AI 02	AI 025
19 km/h		AI 015	AI 015	AI 02	AI 025	AI 025
20 km/h		AI 015	AI 02	AI 02	AI 025	AI 03
22 km/h	AI 015	AI 015	AI 02	AI 02	AI 025	AI 03
25 km/h	AI 015	AI 02	AI 02	AI 025	AI 03	
28 km/h	AI 015	AI 02	AI 025	AI 03	AI 03	
30 km/h	AI 015	AI 02	AI 025	AI 03	AI 03	

As a result of many trials Nufarm is confident with the performance of those two nozzle types and is recommending its use with Nufarm products that require a COARSE spray quality. This recommendation does not exclude the use of other nozzle types with Nufarm products. There are overlapping situations where more than one nozzle size could be recommended.

Nufarm SprayWise®

Paddock Name			
Crop		Crop Stage	
Date		Spray Order No.	
Grower			
Location			
Area Sprayed			
Recommended By			
Operator			
Address			

Map

No-Spray Zone	☐ N/A ☐ Yes (see map)
Neighbours Notified	☐ Date / /

Tank Mix

Water Source	pH	Hardness	Bicarbonates	Others	Total L in Tank

Chemicals/Adjuvants	Rate	Batch No	Min. required Spray quality	No-Spray Zone m (if required)	Total L/kg in Tank
IN MIXING ORDER					

Setup

Sprayer	
L/Ha	
Nozzle Type, Size & Spacing	
Double Line (if applicable)	
Pressure & Spray Quality	
Travel Speed	
Boom Height	

Operator Protection ☐ ☐ ☐ ☐ ☐ ☐

Spraying Conditions

	Time	Wind Speed kph	Wind Direction from	Temperature °C	Humidity	Delta T
Start						
Checkpoint						
Finish						

Pests	

Notes

Nufarm SprayWise®

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN GRAPES			
Situation	**Characteristics**	**Problem**	**Effective Solutions**
Variable Sized Canopies	Ranging from thin 70 cm tall VSP to thick 2 m tall sprawl canopy Rapid growth during season	Hard to determine correct Dilute Volume Correct set-up of sprayer	Use Spraywise Dilute (page 25) Check set-up with markers and adjust if necessary (page 42 and 57)
Thickness and Canopy Structure	Ranging from single to multiple layers of leaves Softness of leaves can create enhanced filing effect	Penetration	Give your sprayer time to penetrate. Test with markers (page 42 and 57) for minimum speed. Use soft, turbulent airflow (Croplands Quantum Mist™, page 18)
Early Season Application	Small target lures into using incorrect water volume	Underdosing	Use Spraywise Dilute (page 25)
Berry Surface	Verry waxy and reppellent	Difficult to deposit droplet Difficult to achieve even spread Difficult to deposit on back of bunches	Use Du-Wett (page 38) or other adjuvants (page 73 to 75), FINE droplets
Bunch Tightness	Berries touch and create ensealed areas within bunch	Coverage inside the bunch	Use Du-Wett (page 38) or increase water volume for botrytis sprays
Bunch Line Spraying	Spray targeted to approxamately only half of the canopy	Overdosing, adjusting spray volume	Use Spraywise Dilute (page 25)
Drift	Urban sprawl	Public concerns	Use coarser droplets and spread with Nufarm Du-Wett® (page 61) Spray into the crop (Croplands Quantum Mist™), rather than up (page 61) Grow hedges (page 61)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)
Water Source	high pH	Alkaline hydrolysis (breakdown) of e.g. Lepidex	Use LI 700® (page 68)

Nufarm

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN MACADAMIAS			
Situation	**Characteristics**	**Problem**	**Effective Solutions**
Old Tall Trees	Canopy above 10 m high	Coverage in the top of the tree	Spray equipment - Quantum tower (page 18) Hybrid sprayer (page 19) Gun nozzles (page 9)
Dense Canopy	Difficult to penetrate, especially upper foliage because of angle and distance	Coverage in the top of the tree	Spray equipment - Quantum tower (page 18) Hybrid sprayer (page 19) Gun nozzles (page 9) Check with markers the set-up, adjust (page 42 and 57) Direct more flow to the top (page 52) Use Spraywise Dilute to determine correct Dilute Volume (page 25) Use canopy air displacement theory for sanity check on speed (page 16)
Nutlet Location	Location - mostly in top of canopy	Coverage	As above
Nut Size	Size - match head	Deposition/coverage Deposition on back of nutlet	As above Use Nufarm Du-Wett® or Designer® to improve deposition and coverage (page 38)
Pesticide Used	Mainly contact chemicals e.g copper, mancozeb	Deposition/coverage	Use Nufarm Du-Wett® or Designer® to improve deposition and coverage (page 38)
Drift Windy Days	Urban sprawl Loss of chemical	Public concerns	Use coarser droplets and spread with Nufarm Du-Wett® (page 61) Spray into the crop (Croplands Quantum Mist™), rather than up (page 61) Grow hedges (page 62)
Water Source	high pH	Alkaline hydrolysis (breakdown) of e.g. Lepidex	Use LI 700® (page 68)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN AVOCADOS			
Situation	**Characteristics**	**Problem**	**Effective Solutions**
Old Tall Trees	Canopy above 8 m high	Coverage in the top of the tree	Spray equipment - Quantum tower (page 18) Hybrid sprayer (page 19) Gun nozzles (page 9)
Dense Canopy	Difficult to penetrate, especially upper foliage because of angle	Coverage in the top of the tree	Spray equipment - Quantum tower (page 18) Hybrid sprayer (page 19) Gun nozzles (page 9) Check with markers the set-up, adjust (page 42 and 57) Direct more flow to the top (page 52) Prune out dead limbs and twigs. Prune lower limbs to reduce humidity within the canopies by improving air circulation. Mature orchards with touching canopies should be thinned Use Spraywise Dilute to determine correct Dilute Volume (page 25) Use canopy air displacement theory for sanity check on speed (page 16)
Fruit Surface	Very rough, waxy and repellent	Difficult to deposit droplet Difficult to achieve even spread Difficult to deposit on back of fruit Fruit surface can be sensitive	Use Nufarm Du-Wett®, FINE droplets (page 38) Achieve even spread and no dripping points, use Nufarm Du-Wett® (page 38)
Drift	Urban sprawl	Public concerns	Use coarser droplets and spread with Nufarm Du-Wett® (page 61) Spray into the crop (Croplands Quantum Mist™), rather than up Grow hedges (page 62)
Water Source	high pH	Alkaline hydrolysis (breakdown) of e.g. Lepidex	Use LI 700® (page 68)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN MANGOES			
Situation	Characteristics	Problem	Effective Solutions
Young Tree Rows Far Apart	Distance from sprayer to tree above 4 m	Reach in windy conditions	Increase airflow
Upper Canopy in Tall Trees	Difficult to reach because of angle and distance	Coverage in the top of the tree	Spray equipment - Quantum tower (page 18) Hybrid sprayer (page 19) Gun nozzles (page 9) Check with markers the set-up, adjust (page 42 and 57) Direct more flow to the top (page 52) Use Spraywise Dilute to determine Dilute Volume (page 25) Use canopy air displacement theory for sanity check on speed (page 16)
Fruit Surface		Difficult to deposit on back of fruit Fruit surface can be sensitive	Use Nufarm Du-Wett®, FINE droplets (page 38) Achieve even spread and reduce dripping points, use Nufarm Du-Wett® (page 38)
Drift	Urban sprawl	Public concerns	Use coarser droplets and spread with Nufarm Du-Wett® (page 61) Spray into the crop (Croplands Quantum Mist™), rather than up (page 61) Grow hedges (page 62)
Water Source	high pH	Alkaline hydrolysis (breakdown) of e.g. Lepidex	Use LI 700® (page 68)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN POTATOES			
Situation	Characteristics	Problem	Effective Solutions
Dense Canopy	Moist microclimate with little access for spray solution	Coverage inside the canopy	Keep crop as clean as possible before canopy closes Increase water volume. The Dilute Volume is approximately 1000L/ha Use Du-Wett with lower volumes (page 38) Check for coverage with markers and adjust (page 42 and 57) Spray in angles with mixture of FINE and COARSE droplets (page 13) Consider air assist sprayer if not too dusty (page 20)
Drift Windy Conditions	Urban sprawl, waterways Loss of chemical	Contamination Few good application days	Use coarser droplets and achieve coverage with Nufarm Du-Wett® (page 61) Grow hedges (page 62)
Water Source	high pH	Alkaline hydrolysis (breakdown) of e.g. dimethoate	Use LI 700® (page 68)
Irrigation	Frequent overhead irrigation	Washing surface active chemicals off	Use Bond in Dilute and Designer in Concentrate Volumes (page 78)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN CUCURBITS			
Situation	Characteristics	Problem	Effective Solutions
Dense Canopy	Moist microclimate with little access for spray solution	Coverage inside the canopy	Keep crop as clean as possible before canopy becomes too dense Increase water volume. The Dilute Volume is approxamately 1000L/ha Use Nufarm Du-Wett® with lower volumes (page 38) Check for coverage with markers and adjust (page 42 and 57) Spray in angles with mixture of FINE and COARSE droplets (page 13) Consider air assist sprayer if not too dusty (page 20)
Drift Windy Conditions	Urban sprawl, waterways Loss of chemical	Contamination Few good application days	Use coarser droplets and achieve coverage with Nufarm Du-Wett® (page 61) Grow hedges (page 62)
Water Source	high pH	Alkaline hydrolysis (breakdown) of e.g. Lepidex	Use LI 700® (page 68)
Irrigation	Frequent overhead irrigation	Washing surface active chemicals off	Use Bond in Dilute and Designer in Concentrate volumes (page 78)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN ONIONS			
Situation	Characteristics	Problem	Effective Solutions
Very Waxy Surface	Repellent	Deposition of droplets Covering the back Spread of droplets	Nufarm Du-Wett® (page 38) Spraying in angles (page 13) Consider air assist sprayer if not too dusty (page 20)
Drift	Urban sprawl, waterways	Contamination, public concern	Use coarser droplets and achieve coverage with Nufarm Du-Wett® (page 61)
Windy conditions	Loss of chemical	Few good application days	Grow hedges (page 62)
Irrigation	Frequent overhead irrigation	Washing surface active chemicals off	Use Bond in Dilute and Designer in Concentrate volumes (page 78)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)

MAIN APPLICATION AND COVERAGE ISSUES IN POMEFRUIT			
Situation	Characteristics	Problem	Effective Solutions
Cryptic insect and mite pests Pests in top of tree e.g. LBAM	Hidden Harder to reach because of angles and distance	Getting active to them	check set-up with markers (page 42 and 57) Release droplets closer to top - Croplands Quantum Mist™ or valute (page 18) Direct more flow to the top (page 52) Use Spraywise Dilute to determine correct Dilute Volume (page 25)
Drift Windy conditions	Urban sprawl Loss of chemical	Public concerns contamination	Use coarser droplets and spread with Nufarm Du-Wett® (page 61) Spray into the crop (Croplands Quantum Mist™), rather than up (page 61) Grow hedges (page 62)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)
Water source	high pH	Alkaline hydroyisis (breakdown) of e.g. Lepidex	Use LI 700® (page 68)

APPENDIX

MAIN APPLICATION AND COVERAGE ISSUES IN CITRUS			
Situation	**Characteristics**	**Problem**	**Effective Solutions**
Very Dense Canopy	Hidden insect and mite pests inside canopy, e.g. on bark, underneath calyx	Getting actives to pest	tubular airflow to open canopy (Croplands Quantum Mist™) (page 18) slow driving speed (page 16) high water volumes - use Spraywise Dilute (page 25) check set-up with markers (page 42 and 57) Use canopy air displacement theory for sanity check on speed (page 16) Use of adjuvants (Activator)
High Volume/Slow Speed	Time consuming	Low efficiency	Concentrate spraying with Nufarm Du-Wett® (page 38)
Drift	Urban sprawl	Public concerns	Use coarser droplets and spread with Nufarm Du-Wett® (page 61) Spray into the crop (Croplands Quantum Mist™), rather than up (page 61) Grow hedges (page 62)
Foaming	Nuisance when filling up and spraying	Loss of time	Use Activator® as defoamer (page 67)
Water Source	high pH	Alkaline hydrolysis (breakdown) of e.g. dimethoate	Use LI 700® (page 68)