Spray application: the importance of calibration

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Introduction

Calibration is the process of accurately determining the output of a sprayer or any other application equipment. One of the most important considerations when applying chemicals should be: is the right amount of chemical being applied? This article is designed to help growers achieve desired chemical application and canopy coverage.

Distance based calibration or unit canopy row

The unit canopy row (UCR) method enables chemical rates and spray volumes to be calculated according to the canopy size. It is an accurate method to ensure a consistent delivery of the right dose of chemical to the canopy. The UCR method assumes 30 L of spray mixture is required to wet a vine canopy 1 m high x 1 m wide and 100 metres in length (Figure 72) to the point of run-off. Depending on canopy type and density, this figure can be 20–40 L per 100 m.

Dilute spray volume (L/100 m) =
20 to 40 L/UCR (30 L assumption) x
canopy height (m) x canopy width (m)

Distance unit

Spray volumes are expressed in litres per 100 metres and the unit for calibration is a 100 metre row length. When measuring grapevine canopies, ignore sparse canes protruding in any direction and measure to where the canopy is reasonably continuous.

Dilute spraying

Actual spray volume (spray volume calculator)

Using pre-calculated rates (Table 19), look up the actual spray volume for the sprayer in litres/100 m, based on travel speed in km/h and the total nozzle flow rate for all the nozzles in litres/minute.

Required dilute spray volume

The required dilute spray volume is the litres per 100 m that a sprayer needs to deliver to wet the canopy to the point of run-off. The term ‘point of run-off’ is usually defined as the point at which spray starts to run-off the surface of a leaf or bunch, but this point can be difficult to clearly identify.

Grapevine canopy size calibration charts such as that shown in Table 18 can be useful to indicate the required dilute spray volume (L/100 m) to wet various sized vine canopies to the point of run-off.

For dilute spraying to the point of run-off, simply adjust the actual spray volume for the sprayer to match the required dilute volume – calculated by the UCR method or estimated from Table 18. Locate your desired L/100 m on the spray volume calculator (Table 19) and read the estimated travel speed and total required sprayer flow rate (L/min). Adjustments to actual spray volume are made by:

- selecting the appropriate nozzle size
- adjusting pressure (within the pressure range recommended for the nozzle)
- adjusting the travel speed (travel speed is normally set by the available air volume, so only make minimal adjustments to speed).

Example to select a total nozzle flow rate:

1. suppose your canopy size is 1 m x 1 m and from Table 18 you select 30 L per 100 m as the required dilute spray volume
2. tractor speed is 8 km/h
3. from the spray volume calculator (Table 19), cross reference your travel speed (8 km/h) and the spray volume of 31 L/100 m to locate the total nozzle flow rate, i.e. 40 L/min.

For dilute spraying (to the point of run-off) the total amount of chemical to put into the spray vat = dilute label rate (amount of product per 100 litres) × volume of tank (litres) ÷ 100.

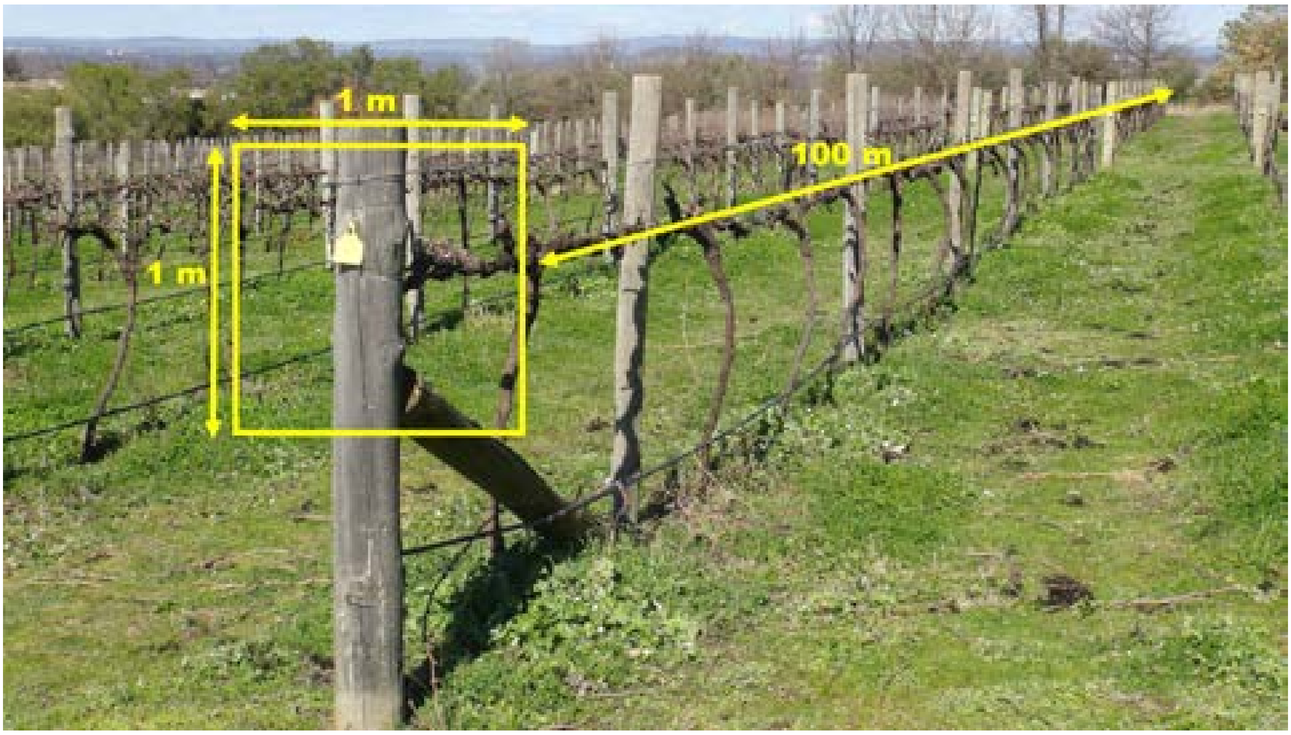
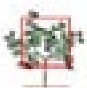
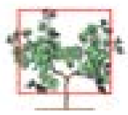
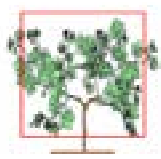
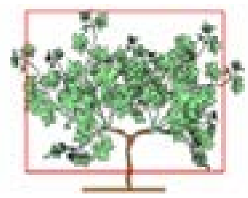
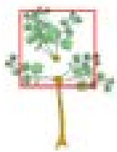
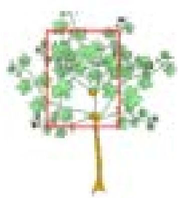
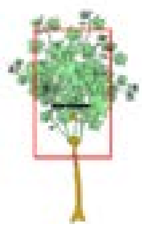


Figure 72. Unit canopy row (UCR). Photo: Adrian Englefield, NSW DPI.

Table 18. Grapevine canopy size calibration charts.

	Up to 0.5 × 0.5 m	Up to 1 × 1 m	Up to 1.5 × 1.5 m	Up to 2 × 2 m and above
Sprawl canopy				
Theoretical spraying volume L/100 m	10–20	20–40	45–60	60–90

	Up to 0.5 × 0.5 m	Up to 1 × 1 m	Wires up, up to 1.5 × 0.5 m	Up to 2 × 0.5 m
VSP canopy				
Theoretical spraying volume L/100 m	10–20	20–40	30–55	45–75

Adapted from: Radunz L. New label directions for spraying.

Table 19. Grapevine spray volume calculator (L/100 m).

Speed in kilometres/hour								Total nozzle flow (L/min)
3	4	5	6	7	8	9	10	
8	6	4.8	4	3.4	3	2.7	2.4	4
12	9	7.2	6	5.1	4.5	4	3.6	5
16	12	9.6	8	6.9	6.0	5.3	4.8	8
20	15	12	10	8.6	7.5	6.7	6	10
24	18	14.4	12	10.3	9	8	7.2	12
28	21	16.8	14	12	10.5	9.3	8.4	14
32	24	19	16	14	12	11	10	16
36	27	22	18	15	14	12	11	18
40	30	24	20	17	15	13	12	20
44	33	26	22	19	17	15	13	22
48	36	29	24	21	18	16	14	24
52	39	31	26	22	20	17	16	26
56	42	34	28	24	21	19	17	28
60	45	36	30	26	23	20	18	30
64	48	38	32	27	24	21	19	32
68	51	41	34	29	26	23	20	34
72	54	43	36	31	27	24	22	36
76	57	46	38	33	29	25	23	38
80	60	48	40	34	31	27	24	40
84	63	50	42	36	32	28	25	42
88	66	53	44	38	33	29	26	44
92	69	55	46	39	35	31	28	46
96	72	58	48	41	36	32	29	48
100	75	60	50	43	38	33	30	50
104	78	62	52	45	39	35	31	52
108	81	65	54	46	41	36	32	54
112	84	67	56	48	42	37	34	56
116	87	70	58	50	44	39	35	58
120	90	72	60	51	45	40	36	60
130	98	78	65	56	49	43	39	65
140	105	84	70	60	53	47	42	70
150	113	90	75	64	56	50	45	75
160	120	96	80	69	60	53	48	80
170	128	102	85	73	64	57	51	85
180	135	108	90	77	68	60	54	90
190	143	114	95	81	71	63	57	95
200	150	120	100	86	75	67	60	100
220	165	132	110	94	83	73	66	110
240	180	144	120	103	90	80	72	120
260	195	156	130	111	98	87	78	130
280	210	168	140	120	105	93	84	140
300	225	180	150	129	113	100	90	150
320	240	192	160	137	120	107	96	160
340	255	204	170	146	128	113	102	170
360	270	216	180	154	135	120	108	180
380	285	228	190	163	143	127	114	190
400	300	240	200	171	150	133	120	200
450	338	270	225	193	169	150	135	225
500	375	300	250	214	188	167	150	250
550	413	330	275	236	206	183	165	275
600	450	360	300	257	225	200	180	300
700	525	420	350	300	263	233	210	350
800	600	480	400	343	300	267	240	400
900	675	540	450	386	338	300	270	450
1000	750	600	500	429	375	333	300	500
1200	900	720	600	504	450	400	360	600
1400	1050	840	700	600	525	467	420	700

Concentrate spraying

Concentration factor

Concentrate spraying is the term referred to when spraying with a water volume that is less than that required for dilute spraying (to the point of run-off) while applying the same amount of chemical (per 100 m of canopy) if you were dilute spraying.

Using the spray volume calculator (Table 19), identify your actual spray volume in L/100 m based on the total nozzle flow rate (per row) and desired travel speed. Dividing the required dilute spray volume (litres per 100 m) by the actual spray volume for the sprayer (litres per 100 m) gives the concentration factor. Multiplying the dilute chemical concentration from the label by the concentration factor gives the concentration of chemical required in the tank for concentrate spraying (tank concentrate rate in amount per 100 litres).

Air assisted sprayers (distance based for vine crops)

Step-by-step calibration methods (both dilute and concentrate) for air assisted vineyard canopy spraying are outlined in Table 20. For further copies please visit the DPI Grapes website (www.dpi.nsw.gov.au/grapes).

Boom sprayers

Table 21 outlines a calibration method for ground application boom sprayers. Ground sprays always use a concentration factor of one.

Example:

1. Refer to the Grapevine canopy size calibration chart (Table 18) or use the UCR calculation to determine indicative dilute spray volume (L/100 m).

   i.e. for a canopy size of 1.5 m × 1.5 m, you select 60 L per 100 m as the required dilute spray volume.

2. Refer to the spray volume calculator (Table 19) and determine the spray volume delivered by your sprayer (actual spray volume).

   i.e. for a travel speed of 8 km/h and the total flow rate of all nozzles is 26 L/min, then the actual spray volume for the sprayer is 20 L/100 m.

3. Determine the chemical concentration factor required by dividing the required dilute spray volume (L/100 m) by the actual spray volume for the sprayer (L/100 m).

   Concentration factor = dilute spray volume (60 L/100 m) ÷ actual spray volume (20 L/100 m) = 3.

4. Calculate the amount of chemical required (per 100 L) using the calculated concentration factor.

   i.e. if the dilute label recommendation is 500 g/100 L, add 500 g/100 L × 3 = 1,500 g/100 L to the spray tank.

The total amount of chemical to put in the vat
=
chemical rate (per 100 L from label × concentration factor) × volume of tank (L) ÷ 100.

Spray applications: the importance of calibration

Table 20. Calibration method for air assisted sprayers (distance based for tree and vine crops) can be used to calculate and record dilute (Parts A–G) and concentrate (Parts H–I) spray applications in the vineyard.

Part A: Crop and chemical			
Chemical used (from label)			
Rate (from label)			mL or g/100 L (**CR**)
Vine height and width			m × m
Canopy density			sparse/medium/dense
Part B: Spray equipment			
Item to be calibrated			
Spray tank capacity			L (**T**)
Select appropriate ground speed			km/hr, gear, rpm
Record spray operation pressure			kPa or bar
Record nozzle type and size in the spray unit. Check the rated water output using nozzle charts. On some sprayers, e.g. air blast, more than a single nozzle type/size may be used.		type/size	rated output
		1 /	1 mL/min
		2 /	2 mL/min
		3 /	3 mL/min
		4 /	4 mL/min
Part C: Measuring nozzle output and calculating total spray output or flow rate			
Record the output from every nozzle for 1 minute. For air-shear and rotary nozzles, disconnect the nozzle delivery hose on the delivery side of the flow restrictor. Replace any nozzles with an output that varies by more than ± 5% from the output specified in the manufacturer's spray chart.			Total spray output (add all nozzles) L/min (**O**)
Part D: Measuring ground speed			
Actual ground speed*	$\frac{\text{Distance covered (m)} \times 3.6}{\text{Time taken (seconds)}}$	$\frac{(\quad) \times 3.6}{(\quad)}$	km/hr (**S**)
*To calculate the actual ground speed: Measure a set distance, e.g. 100 m Make sure that the spraying conditions are like those in the area that you will be spraying Time how long it takes using the appropriate gears and revs.			
Part E: Calculating dilute spray volume per 100 m canopy			
Use appropriate crop spray volume calculator table (Table 19). Select speed column (as per measured ground speed – Part D (**S**)) in table and cross tabulate with total spray output/flow rate (Part C (**O**)) row in table to obtain L/100 m in canopy row.			L/100 m (**DV**)
Part F: Checking calculated spray volume = required spray volume for dilute spraying			
Required spray volume per 100 m of canopy (Table 18)			L/100 m (**RV**)
Calculated spray volume per 100 m of canopy from actual nozzle output and measured speed (Part E)			L/100 m (**DV**)
Does the required spray volume match the calculated spray volume?			Yes/No
If yes, no further action required. If no, replace nozzles and repeat C.			
Part G: Calculating amount of chemical to add to spray tank for dilute spraying			
$\frac{\text{Rate (mL or g) } \mathbf{CR} \times \text{Spray tank capacity (L) } \mathbf{T}}{100}$		$\frac{(\quad) \times (\quad)}{100}$	L
Part H: Calculating concentration factor for concentrate spraying and concentrate rate			
Required spray volume per 100 m of canopy (**RV**)			L/100 m
Calculated spray volume per 100 m of canopy (**DV**)			L/100 m
Use required spray volume and measured spray volume to calculate concentration factor			
$\frac{\text{Required spray volume } (\mathbf{RV})}{\text{Measured spray volume } (\mathbf{DV})}$		$\frac{(\quad)}{(\quad)}$	factor (**CF**)
Use rate and concentration factor to calculate concentrate rate			
Rate (mL or g/100 L) **CR** × Concentration factor **CF**		( ) × ( )	/100 L (**R**)
Part I: Calculating amount of chemical to add to spray tank for concentrate spraying			
$\frac{\text{Concentrate rate } \mathbf{R} \times \text{Spray tank capacity } \mathbf{T}}{100}$		$\frac{(\quad) \times (\quad)}{100}$	L

CR = chemical rate; T = tank capacity; O = output; S = speed; DV = dilute spray volume; RV = required spray volume; CF = concentration factor; R = concentrate rate.
Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.

Table 21. Calculation method for ground application boom sprays.

Part A: General information			
Item to be calibrated			
Spray tank capacity			L (**T**)
Area to be sprayed			ha (**A**)
Chemical used			
Part B: Recording			
What is the minimum water application rate — if any (from the label)?			L/ha
Select the correct chemical application rate from the label			L/ha (**CR**)
Select an appropriate ground speed			gear rpm
Record spray operation pressure			kPa or bar
Record nozzle type and size Check the rated water output using nozzle charts. Rated output			type size mL/min
Record minimum boom height above target for these nozzles			cm
Part C: Measuring			
Record the output from every nozzle for 1 minute. Replace any nozzles with an output that varies by more than ± 5% from the output specified in the manufacturer's spray chart.			Total spray output (add all nozzles) L/min (**O**)
Record effective spray width in metres by measuring the distance across the outside nozzles and adding the distance between two nozzles.			m (**W**)
Part D: Calculating			
Actual ground speed*	Distance covered (m) × 3.6 / Time taken (seconds)	( ) × 3.6 / ( )	km/hr (**S**)
*To calculate the actual ground speed: Measure a set distance, e.g. 100 m Make sure that the spraying conditions are like those in the area that you will be spraying Time how long it takes using the appropriate gears and revs. Now you can calculate the water application rate, how much chemical you will need to mix in each tank and how many tank loads you will need to do the whole job. Follow the steps below.			
1. Copy the answers you worked out so far into the spaces below. You will need these numbers to do the calculations. The highlighted letters in brackets tell you the step where the answer is.			
Total spray output L/min (**O**)	Effective spray width m (**W**)	Actual ground speed km/hr (**S**)	
2. Work out the water application rate by using the numbers you have recorded above. Put these numbers in the correct places in the calculation below.			
Water Application rate: (**O**) × 600 / (**W**) × (**S**)	( ) × 600 / ( ) × ( )	( ) / ( )	L/ha (**WR**)
Does this water appliction rate satisfy the label requirements? (See Part B) If not, how could you change this rate to meet the requirements?			Yes/No
3. Now that you know the water application rate you can calculate how much chemical you need to mix in each tank.			
Chemical application rate	L/ha (**CR**)	Spray tank capacity	L (**T**)
How much chemical to mix in each tank?	**CR** (L/ha) × **T** (L) / **WR** (L/ha)	( ) × ( ) / ( )	
4. Finally, you can now work out how many tank loads you will need to do the job			
Spray mix needed for the job	**A** (ha) × **WR** (L/ha)	( ) × ( )	
Number of tanks needed	**M** (L) / **T** (L)	( ) / ( )	
To cross-check your calculations: Number of tanks (step 4 above) × how much chemical to mix in each tank (step 3 above) = Area to be sprayed (**A**) × chemical rate (**CR**)			
Automatic rate controller			
Many boom sprayers are set up with automatic rate controllers that will allow a constant per hectare output with varying speeds by adjusting the flow rate. The two main factors governing the system are again the precise measuring of speed and flow rate. At the initial set up of the machinery, precise inputs into the rate controller would have assured the precise operation. However, over time, machinery will wear, therefore, it is important to check if initial inputs are still in calibration.			

O =output; W =width; S =speed; CR =chemical rate; T =tank size; WR=water rate; A =area; M =spray mix. Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.

Spray coverage assessment

After chemical application in the vineyard, assessment of spray coverage is a critical to ensure correct calibration (dilute or concentrate spray volume) and canopy coverage.

Clay

Kaolin clay-based 'sunscreen' products are used within the viticulture industry to counteract the unwanted effects of post-véraison heatwaves. Additionally these products can be used to assess spray coverage on all parts of the canopy and bunch zone. They can be applied to both leaves (Figure 73 and Figure 74) and bunches (Figure 75). Always check with your winery or grape purchaser's requirements before spraying sunscreen products.

Figure 73. Clay-based sunscreen on leaves. Photo: Adrian Englefield, NSW DPI.

Figure 74. Clay-based sunscreen on leaves. Photo: Adrian Englefield, NSW DPI.

Figure 75. Clay-based sunscreen on bunches. Photo: Adrian Englefield, NSW DPI.

Fluorescent pigment/droplet number rating chart (DRC) technique

This technique only requires a fluorescent light and is simple to undertake with minimal training. It can be used to accurately determine the point of first run-off, the uniformity of canopy coverage and whether sufficient chemical has been applied on all plant surfaces. It can also be used to evaluate off target deposition.

Visual rating

Fluorescent pigment is added to a small volume of water in the spray vat and sprayed onto the foliage. Deposits are assessed directly on foliage using a black light (Figure 76) or on picked foliage in a darkroom. With training, the droplet size and number per cm^2 is estimated with reference to a droplet number rating chart (DRC; Figure 77).

Figure 76. Fluorescent pigment assessment. Photo: Adrian Englefield, NSW DPI.

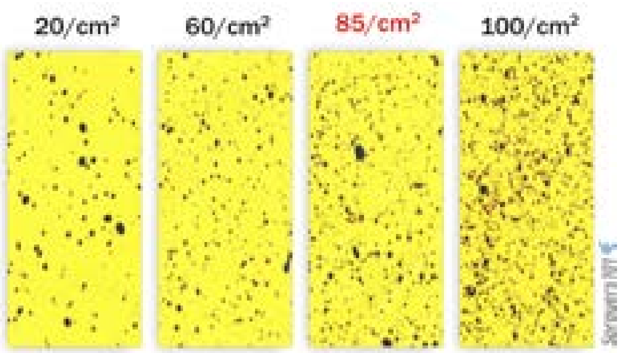


Figure 77. Droplet rating chart. For most applications, 85 droplets per square centimetre and 10-15% coverage represent sufficient coverage. Photo: Jason Deveau, Sprayers 101.

Efficacy

With dilute (high volume) spraying, good efficacy can be expected with 200 droplets per cm^2 or higher (up to run-off) with fine droplets (or 25 per cm^2 with medium droplets). These numbers should be attained on at least 70% of foliage including:

- difficult to reach foliage, such as lower leaf surfaces, inner and upper canopy sites
- sheltered side of bunches or fruit.

In exposed sites, these droplet numbers will normally be exceeded on about 90% of the foliage.

Dose rating

The DRC is also used to estimate the amount of chemical deposited on the grapevine canopy. The volume of spray liquid deposited is read off the DRC chart and the amount of chemical deposited is calculated by:

Amount of chemical deposited (µg or µL/cm^2)
= deposit volume (µL/cm^2) × chemical concentration in the vat (gm or L/100 L) ÷ 100

Note: Chemical concentration in the vat = dilute label concentration × concentration factor.

An adjustment calculation may be needed to determine the amount of active ingredient deposited:

Amount of active ingredient (AI) deposited (µg or µL/cm^2)
= amount of chemical deposited (µg or µL/cm^2) × % AI in the product ÷ 100.

Water sensitive papers

Water sensitive papers are available from most pesticide retailers and spray equipment manufacturers. They are attached to foliage at various places within the vine (Figure 78). They give a simple, cheap and rapid guide to spray coverage, especially for hydraulic boom and airblast sprayers that produce medium to coarse droplets (Figure 79). However, they are indicative only, as they underestimate the deposition of fine droplets. These fine droplets have a greater capability of reaching the bunch zone (middle of canopy).

Figure 78. Water-sensitive paper before spraying. Photo: Adrian Englefield, NSW DPI.

Figure 79. Water-sensitive paper after spraying. Photo: Adrian Englefield, NSW DPI.

SnapCard

SnapCard (Figure 80) is a free combined smartphone and website app, developed by The University of Western Australia and the Department of Agriculture and Food. SnapCard provides growers with access to a valuable decision support tool that can be used in two important ways:

1. it will predict spray coverage based on 'current' conditions e.g. time of day, tractor speed, spray nozzles, spray volume, boom height, adjuvants and weather conditions
2. it compares obtained spray coverage, measured by water sensitive spray cards, with 'expected' spray coverage based on agronomic variables, weather conditions and spray settings.

With your smartphone *in situ*, you can now use SnapCard to quantify spray coverage from a water sensitive spray card. In addition you can also keep archive records of your spray settings and coverages. SnapCard app download: https://itunes.apple.com/au/app/snapcard/id732696197?mt=8

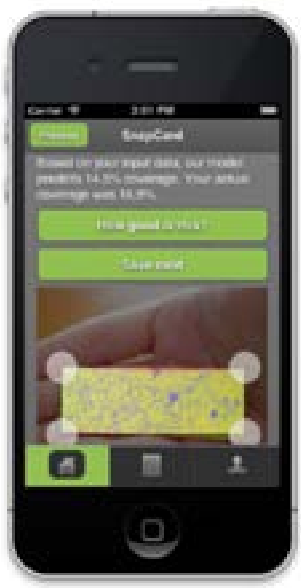


Figure 80. The SnapCard app.

Nozzles

Spray nozzle choice is one of the most important decisions when using sprayers. All nozzles are prone to wear and should therefore be checked regularly and replaced if necessary. Testing a nozzle is easy: simply measure the output from each nozzle when the sprayer is operating at the normal operating pressure for a given time, such as 1 minute. Any nozzle that is delivering 5% more or less than the rated output (refer to manufacturer's nozzle chart) should be replaced.

Types of nozzles

Different nozzles are designed for different applications, including fungicide or herbicide application. There are many types of nozzles including:

- air aspirated/venturi
- anvil
- banding or even spray
- double outlet/twin jet
- flat fan – anvil hybrid
- flat fan – drift reduction
- flat fan – standard
- full cone
- hollow cone
- off-centre
- twin fluid.

Nozzles are coded to the International Organisation for Standardisation (ISO standards) which specify colours for flow rates. Standard colours are shown in Table 22 and multiplication factors for adjusting nozzle flow rates are outlined in Table 23. As a general rule, it is better to use pressure to adjust flow rates downwards rather than upwards. In any case, pressure adjustments should be used only for fine-tune calibration.

Table 22. Nozzle outputs and ISO colour coding.

Nozzle	Output at 3 bar in litres/minute	ISO colour
01	0.4	
015	0.6	
02	0.8	
03	1.2	
04	1.6	
05	2.0	
06	2.4	

For more details, refer to manufacturer's nozzle charts.

Table 23. Multiplication factors for adjusting nozzle flow rates.

Increase flow rate by %	Multiply pressure by	Decrease flow rate by %	Multiply pressure by
5	1.10	5	0.90
10	1.21	10	0.81
15	1.32	15	0.72
20	1.44	20	0.64
30	1.69	25	0.56
40	1.96	30	0.49
50	2.25	35	0.42
60	2.56	40	0.36
75	3.06	45	0.30
100 (2 × original flow)	4 (4 × original pressure)	50 (½ original flow)	0.25 (¼ original pressure)

Source: Calibrating field sprayers, Universtiy of Missouri-Columbia.

Extra terms used to describe droplet size produced by nozzles:

VF – very fine droplets (mist)

F – fine droplets (mist)

M – medium droplets

C – coarse droplets

VC – very coarse droplets

AI (air-induction nozzles) – large droplets that splatter.

Tips to maintain nozzle performance

Nozzle filters

The nozzle filter (strainer), located directly behind the nozzle tip, must be the correct size to filter out all unwanted particles. Booms which do not have self-aligning nozzles must have their nozzles offset by 10–15 degrees.

Check valves

Check valves are used to prevent nozzles dripping when the boom spray is turned off. They can be ball check valves but are more commonly diaphragm valves, opening at a pre-set pressure. Ball valves are not suitable for wettable powders. Select valves that can withstand the pressure when in use and which have sufficient flow capacity for the particular task.

Operation of equipment

Prepare your sprayer and manipulate the droplet spectrum to suit the target so that you reduce wastage and improve the effectiveness of the pesticide. Adjustments include setting the correct pressure and height above the target. Set the height to suit the target and the amount of overlap required.

Lower pressures cause:

- droplet sizes to increase
- narrow fan angles
- decreased risk of evaporation
- decreased risk of drift to non-target areas
- reduced rate of application.

Higher pressures cause:

- droplet sizes to decrease
- wider fan angles
- increased risk of evaporation
- increased risk of drift to non-target areas
- increased rate of application.

Larger nozzle tips increase application rates and droplet size and reduce:

- drift potential
- risk of evaporation
- effective coverage.

Adjuvants: stickers, wetting agents and surfactants

What are adjuvants?

Adjuvants are supplements that are added to the formulation to improve the efficacy of the active ingredient or the ease of application of the product. They are usually added by the manufacturer during the formulation, but some must be added just prior to use (read label instructions). Water or surfactants are examples of adjuvants. They may be used to:

- assist in the initial formulation of a chemical
- maintain long-term stability of the product
- increase or decrease the toxicity and the activity of the chemical
- help in the uptake of the chemical by the target organism
- help with the application of the chemical to the target organism.

Adjuvants that enhance efficacy

- surfactants, such as wetting agents, emulsifiers, anti-foaming agents, spreaders, dispersants
- stickers
- penetrants (crop oils)
- extenders
- humectants to reduce the loss of moisture and increase drying time
- drift control agents
- dyes
- water softeners
- fertilisers
- anti-caking agents to prevent lumps forming in powders and granules and to promote flow.

Adjuvants that improve ease of application

- emulsifiers, anti-foaming agents
- acidifying and buffering agents
- compatibility agents
- drift control agents
- water conditioners
- anti-caking agents.

What are surfactants?

Surfactants are adjuvants that reduce or modify the surface tensions which exist between two or more incompatible substances such as water and oil. Surface tension acts like a skin around each of the substances, preventing them from mixing together. It can exist in formulations between a concentrate and a carrier, between a spray liquid and the surface of the target organism, or between the spray droplet and air. Surfactants are used to:

- prevent the chemical active ingredient and the carrier from separating
- allow ready mixing of concentrates with secondary carriers before use but after purchase
- improve the spread or dispersion of sprays rather than have individual droplets on the target surface. Droplets with a high surface tension will be more likely to bounce off the leaf surface while those with a low surface tension will tend to spread on contact and be absorbed.

Factors affecting adjuvant use

Be careful

Although an adjuvant may be beneficial in one situation, it may not be so in others. Some adjuvants can affect the spray pattern of chemicals and some can increase the proportion of fine droplets, posing a greater threat to spray drift management. If you add adjuvants before use, do so only according to the manufacturers' mixing instructions; otherwise, you might cause crop damage, decreased chemical activity or prevent proper mixing. **Always follow the instructions on the label.**

Crop safety

Adding an adjuvant can reduce herbicide selectivity and thereby increase crop damage. This is not an issue for fallow or pre-emergent herbicides.

Effectiveness or activity

Adjuvants are usually added to increase the effectiveness of chemicals. However, the wrong type or rate can reduce effectiveness.

Tank mixing

Mixing chemical products is sometimes desirable to improve the efficacy of chemical application. It can save time, labour, machinery and costs. However, you need to take great care if you mix products and always follow the manufacturer's recommendations. Two or more chemicals are considered to be compatible when mixing if there is no damage to the sprayed crop (phytotoxicity) or reduction of the efficacy of the active ingredient. Certain formulations may react when mixed together resulting in undesirable results:

Sometimes 1 + 1 = 2

The two products may have a simple **additive** effect, i.e. the final result is equal to the sum of the effects of the two products if they were used separately.

Sometimes 1 + 1 = less than 2

The two products may have an **antagonistic** effect, i.e. the final result can be less than the sum of the two products used separately. This can be due to a physical or chemical reaction, for example when an emulsion separates into layers without chemical change, or when two mixed chemicals react to form a new undesirable chemical.

Sometimes 1 + 1 = more than 2

The two products may have a **synergistic** effect, i.e. the final result may be greater than the sum of the two products used separately. This type of enhancement is usually desirable, especially by manufacturers and users.

Sometimes 1 + 1 = less than 1

Farm chemical mixtures may be **phytotoxic** to plants which are not affected by the individual products used separately. Sometimes this can happen when mixing occurs on the plant itself. Another problem can occur when chemicals are mixed is 'mayonnaising' of non-compatible products. This means that the mixture becomes thick and creamy and it can lead to difficult blockages in the application equipment.

General guidelines for avoiding incompatibility

- mix only those products you know are compatible
- avoid mixing more than two products at a time because it increases the risk of incompatibility
- avoid mixing emulsifiable concentrates with wettable powders
- follow the guidelines for the order of mixing (see below)
- mix one product in the tank first before mixing the second
- if in doubt, try a sample mix by mixing small quantities of the product in the same proportion as you intend to used them and observe the result. If the mixture appears satisfactory, spray it onto small area of the vineyard and after a few days, check for phytotoxicity such as leaf scorching, leaf curl or leaf drop
- always follow all label instructions and compatability guidelines whenever mixing chemicals

Order of mixing

1. add water to fill the spray tank so that it is 70% full
2. start agitation
3. add water conditioning agents if required
4. add water dispersible granules (WG), those in water-soluble bags first. Allow at least 10 minutes for complete dispersion
5. add wettable powders (WP)
6. add suspension concentrates (SC) or flowables
7. add emulsifiable concentrates (EC)
8. add water until the tank is nearly full
9. add water-soluble concentrates
10. add surfactants and oils
11. add soluble fertilisers.

Water quality

Water quality is important when mixing and spraying chemicals. Poor quality water can reduce the activity and efficacy of some chemicals. It can also damage spray equipment by increasing the wear of spray application equipment, nozzles or spray lines, ultimately reducing the uniformity of the spray application. Some agricultural chemicals are more sensitive to poor water quality than others and there may be specific recommendations on the label. Use the cleanest water available to minimise spray failure.

Effects of water quality

Water quality can vary due to source (e.g. bore, dam, rainwater, aquifer), season or after rainfall. There are several characteristics of water quality which affect chemical performance including:

Turbidity

Turbidity is due to suspended clay, silt or fine organic matter. It gives a muddy look to the water and is often noticed in dam water. The tiny particles can absorb or bind the chemical's active ingredient and reduce its effectiveness. Dirty water is also likely to block nozzles and filters, and reduces the sprayer's overall performance and life. As a guide, water is considered dirty when it is difficult to see a 10 cent coin in the bottom of a household bucket of water.

Water hardness

Hardness is due to high levels of dissolved calcium, magnesium or manganese. Hard water will not lather with soap. The dissolved ions can bind to the chemical molecules so that they cannot enter the target, or not enter at an effective rate, or cause the chemical complex to precipitate out of the solution. Hard water is often a problem with bore water and some chemicals are sensitive to it. Susceptible chemicals often have agents added to overcome this problem.

Water pH

The pH of water is a measure of its acidity or alkalinity on a scale of 1 to 14, with 7 being neutral. Water with a pH below 6.5 is considered acidic and above 8 is considered alkaline. Many chemicals undergo alkaline hydrolysis where the active ingredient breaks down into other less effective compounds over time. This is why chemical spray mixes should not be left in tanks overnight. Very acidic water can affect the stability and physical properties of some formulations and should be avoided.

Salinity

Salinity is a measure of the total amount of mineral salts dissolved in water and is measured by electrical conductivity (EC). The EC of bores and dams depends largely on the salt levels in the rock and soil that surrounds them. During a drought, water salinity increases. Very salty water can cause some chemicals to precipitate out of solution and cause inactivation of others. Salinity can also make it difficult to adjust pH with buffer solutions. It can also cause blockages and corrosion in spray equipment and lead to damage of non-target organisms.

Temperature

Very hot or cold water can affect the performance of some chemicals. Refer to chemical labels for further information.

Improving water quality

Water needs to be tested to see whether it will affect chemical performance. There are commercial products available that can reduce pH, soften hard water and clear dirty water. To reduce the effects of water salinity, you may need to mix water from several sources.

Chemical safety: key terms

There are many terms and abbreviations associated with chemical spraying, some of the more common ones are listed in Table 24.

Chemical application record keeping

In NSW, the EPA's Pesticides Regulation (2009) makes it compulsory for all people who use pesticides for commercial or occupational purposes to make a record of their pesticide use (for example a spray diary). Pesticides include herbicides, fungicides, insecticides, fumigants, nematicides, defoliants, desiccants, bactericides and vertebrate pest poisons. A small use exemption, similar to that for training, applies to record keeping. Table 25 contains a useful spray application record keeping template.

Table 24. Key chemical safety terms and their abbreviations.

Term	Abbreviation	Definition	Where you find it
Withholding period	WHP	The interval that must pass between the last time a chemical was applied and when it is permissible to harvest grapes from treated plants.	On the label, immediately below or within the DIRECTIONS FOR USE.
Maximum residue limit	MRL	The maximum amount of pesticide that is allowed to remain in a product when the chemical is used according to the label instructions.	Website for Food Standards Australia New Zealand.
Acceptable daily intake	ADI	The amount of chemical a person can consume each day over their lifetime without harming their health.	Website of Therapeutic Goods Administration.
Acute reference dose	ARfD	The amount of chemical a person can consume each day over a short period of time (such as a single meal or over a day) without harming their health.	Website of Therapeutic Goods Administration.
Re-entry period		The time that must lapse between spraying a vineyard and entering the vineyard without wearing PPE.	On the label as a precaution statement in GENERAL INSTRUCTIONS.
Plant-back period		The time interval required after treatment with a herbicide that has persistent soil residues before planting a new crop that can be affected by the residues.	On the label as a precaution statement in GENERAL INSTRUCTIONS (with or without its own heading) or in the CRITICAL COMMENTS column in the DIRECTIONS FOR USE.
Export harvest interval	EHI	The extended time that must pass between the last time a chemical was applied and the time when you can harvest the grapes from treated plants for export.	On the label with the WHP section immediately below DIRECTIONS FOR USE OR contact the product manufacturer OR contact Wine Australia.

Useful links

Chemical contacts

Distributor/Manufacturer	Website
BASF Australia Ltd	www.basf.com/au/en.html
Bayer CropScience Pty Ltd	www.crop.bayer.com.au
Dow Agrosciences	www.dowagro.com/en-au/australia
DuPont Australia	www.dupont.com.au
Adama Australia Pty Ltd	www.adama.com
Nufarm Australia Ltd	www.nufarm.com
Sinochem	www.sinochem.com.au
Sipcam Pacific Australia Pty Ltd	www.sipcam.com.au
Sumitomo Chemical Australia Pty Ltd	www.sumitomo-chem.com.au
Syngenta Crop Protection Pty Ltd	www.syngenta.com.au

Further reading and acknowledgements

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Browne, B 2017, 'Legal responsibilities in applying pesticides', Orchard plant protection guide for deciduous fruits in NSW 2017–18, NSW Department of Primary Industries.

Essling, M and Lord, A 2017, 'Agrochemicals registered for use in Australian viticulture 17/18, an essential reference when growing grapes for export wine', The Australian Wine Research Institute.

Furness, G 2005, 'Orchard and vineyard spraying handbook for Australia and New Zealand', South Australian Research and Development Institute.

Laffan, J, Blake, A, Troldahl, R, Friis, N and O'Leary, N 2017, 'Chemical application, Resource Manual AQF3', Ed. 6, SMARTtrain chemical safety and training, NSW Department of Primary Industries.

Radunz L, 2001, 'New label directions for spraying: a review of experiences over thge past year', The Australian and New Zealand Grapegrower and Winemaker, 45–46.

Scott, M, Blake, A, Troldahl, R, Friis, N and O'Leary, N 2016, 'Calibration and records supplement, Part 1 and 2', Ed. 3, SMARTtrain chemical safety and training, NSW Department of Primary Industries.

Table 25. An example spray application record keeping document.

<table>
<tr><td colspan="8">Chemical application record</td></tr>
<tr><td colspan="6">Property address:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="3">Owner:</td><td colspan="3">Address:</td><td colspan="2">Phone:</td></tr>
<tr><td colspan="3">Person applying chemical:</td><td colspan="3">Address:</td><td colspan="2">Phone:</td></tr>
<tr><td colspan="4">Spray application area</td><td colspan="4">Situation of use</td></tr>
<tr><td colspan="4" rowspan="8">Spray map including sensitive areas, wind direction, order of treatment</td><td colspan="4">Area sprayed and order of spraying</td></tr>
<tr><td>Block name/ number</td><td>Area (ha)</td><td>Variety</td><td>EL stage</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Pest(s)</td><td></td><td>Pest growth stage</td><td>Pest density</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">GPS reference: S E</td><td colspan="4">Application equipment</td></tr>
<tr><td colspan="4">Comments (including risk control measures for sensitive areas):</td><td>Equipment type</td><td>Nozzle</td><td>Pressure</td><td>Speed</td></tr>
<tr><td colspan="4">No-spray zone (metres):</td><td>Water quality (eg. pH, hardness)</td><td>Droplet size</td><td>Boom height (above target)</td><td>Other:</td></tr>
<tr><td colspan="8">Chemical details</td></tr>
<tr><td>Full product name: (including additives)</td><td>Chemical rate</td><td>Water rate</td><td>Total amount of concentrate</td><td>Total amount of chemical mix used</td><td>Mixing order</td><td>Re-entry period</td><td>WHP</td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">Weather details</td></tr>
<tr><td>Rainfall (amount and time from spraying)</td><td colspan="2">Before: mm</td><td colspan="2">During: mm</td><td colspan="3">After: mm</td></tr>
<tr><td>Time of spraying:</td><td>Temperature °C</td><td>Relative humidity %</td><td>Delta T</td><td>Wind direction from</td><td>Wind speed</td><td colspan="2">Variability eg. gusting speed and direction</td></tr>
<tr><td>Start:</td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Finish:</td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Start:</td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Finish:</td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="8">Clean up</td></tr>
<tr><td colspan="4">Disposal of rinsate:</td><td colspan="4">Decontamination of sprayer:</td></tr>
</table>

Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.