

Vegetable Industry Development Program

Spray Application Basics



Objective

Chemicals play an important role in vegetable production and are regularly used to control insect pests, diseases and weeds. When applying chemicals aim to maximise the amount reaching the target and minimise the amount reaching off-target areas.

Principles of spray application

The majority of chemicals used in vegetable production are delivered in the form of droplets produced from different types of nozzles and spray booms. To maximise spray efficiency, spray droplets must be uniformly distributed on a target surface with minimum losses due to drift, evaporation or run-off. Poor spray application techniques result in:

- reduced control of pests
- yield reduction
- wasted chemicals
- lower returns to the grower.

Knowing the importance of droplet sizes, droplet density and water volume will help spray operators get the best possible results. When targeting the plant, spray droplets should be distributed uniformly over the entire plant, including the underside of the leaves as well as on top of the plant. To achieve this, droplets need to be small enough that they will swirl around as they are deposited onto the plant surface. Large droplets, being heavier, tend to fall straight down and are not usually deflected by air movement so their redistribution within the crop foliage is limited. Large droplets are also more difficult to retain on the leaf surface tending to bounce or roll off, cascading down the foliage and onto the ground. When larger droplets are produced, there are much less of them, meaning there is less likelihood of them reaching the target.

Key Messages

Agricultural chemicals play an important role in vegetable production. For best results:

- Regularly scout crops to accurately identify insect, disease and weed pests
- Select a suitable droplet size and water volume for each spraying job
- Regularly calibrate and maintain spraying equipment using only clean water

Droplet size

Droplets are very small and usually measured in microns (μm) with one micron equalling 0.001mm. When operating at any given pressure, hydraulic nozzles produce a range of droplet sizes. The British Crop Protection Council (BCPC) has classified these ranges of droplet sizes into different classes. This classification is included in most nozzle catalogues and is a useful guide for assessing the suitability for any given spray job.

BCPC Category	Droplet Size	Description	Uses in Agriculture Spraying
Very Fine	<150 μm	Mist or fog	
Fine	150-250 μm	Fine spray	Insecticides and contact herbicides
Medium	250-350 μm	Medium spray	Residual herbicides
Coarse	350-450 μm	Very fine rain	Residual herbicides and foliar fertilisers
Very coarse	450-550 μm	Fine rain	Foliar fertilisers
Extremely coarse	>550 μm	Heavy rain	Foliar fertilisers

Note: Droplets smaller than 80 μm cannot readily be seen by the naked eye



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Droplet density

Droplets not only need to be uniformly distributed over the target area but the density also needs to be sufficient to achieve good results. Different types of chemicals require a different level of droplet density. Systemic type chemicals require a droplet density as low as 20-30 droplets/cm². When targeting mobile insects or using contact fungicides, a higher density of 70-100 droplets/cm² is recommended. The droplet density required will vary with the type of chemical being used. The table below gives a guide to the droplet densities required to ensure adequate levels of control.

Product	Droplets/cm ²
Insecticides	
Mobile insects	60-100
Systemic	20-30
Contact	50-70
Herbicides	
Pre-emergent	20-30
Post-emergent	30-40
Fungicides	
Systemic	20-30
Contact	50-70
Foliar nutrients	20-30

Small droplets - what's wrong with them?

If the droplet size becomes too small they are more affected by drift and evaporation. Unfortunately as droplet size is reduced to improve spray coverage the more susceptible it becomes to airborne drift. The principles of efficient spray application not only aims for good target coverage but also in reducing spray drift and any negative impacts it might have on the environment, public health and property.

Small water based droplets also evaporate rapidly in hot conditions and may disappear before reaching the target. A 50µm droplet will evaporate over 250 times quicker than a 200µm droplet. On a hot day a 50µm droplet may only travel 0.1 to 1m before it disappears while the 200µm and larger droplets have little to no chance of evaporating before reaching its target.

Water rates

Water rate as well as droplet size help determine droplet density. If water rates are too low, it will lead

to insufficient droplet density and poor coverage. If water rates are too high, it will lead to plants dripping with excess pesticide and environmental pollution. Good spray application aims at using a water rate that gives a uniform droplet distribution at the desired density.

There is an important relationship between droplet size, volume and the number of droplets that can be produced from a fixed volume of spray application. As the size of droplets get smaller, a greater number of droplets are produced from the same volume of spray. One 400µm droplet is equal in volume to 64 droplets each of 100µm. You can expect a far better spray coverage on a leaf surface with 64 droplets (at 100µm) than with one droplet (of 400µm).

When beginning a spray program for vegetables with **contact chemicals you need to aim for a density of 50 to 70 droplets/cm²** throughout the whole canopy. This droplet density is below the point of run-off. To achieve a thorough coverage with a conventional boom, you need to **use a minimum water rate of 250 L/ha when the plants are young**. As the crop growth increases, water rates should also increase. The water volume required to achieve sufficient droplet density varies with crop type and foliage density. Aim for a water rate of 500 L/ha to achieve a thorough coverage in most mature vegetable types.

Nozzle selection

Nozzle selection is often based on achieving the required water rate at the desired droplet size. The following is a description of the most popular nozzles used for agricultural spraying.



Hollow Cone Nozzles

Hollow cone nozzles are a popular nozzle for applying insecticides and fungicides. They generally produce a smaller droplet size than most other nozzle types. The characteristic hollow cone shaped spray output is produced when the liquid is forced through slots in the swirl plate (within the nozzle body) then emitted through a narrow orifice.



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Solid Cone Nozzles

Solid cone nozzles have an extra hole in the centre of the swirl plate and produce higher flow rates than a similar size hollow cone nozzle. They are not usually recommended for applying insecticides and fungicides as the increase in flow rate comes with an increase in droplet size. **Solid cone nozzles are more suitable for residual herbicides and foliar fertilisers.**

Flat Fan Nozzles and Double Flat Fan Nozzles



Flat fan nozzles are the most common type of nozzle and can be suitable for many different purposes.

These nozzles have a rectangular or lens shaped orifice which produce a tapered distribution of droplets across the nozzle swath. Uniform coverage is achieved by overlapping each nozzle 30% with the nozzle each side of it. There are many sizes of flat fan nozzles that can operate under various pressures with a wide range of droplet sizes. Double flat fan nozzles produce two spray swaths from the one nozzle body. These nozzles offer the advantage of the spray being directed from two different angles to improving coverage. **These nozzles are suitable for applying insecticides and fungicides if the correct size and pressures are used.**

Turbo and Double Turbo Fan Nozzles



Turbo types are also a common type of nozzle and suitable for broadcast spraying. These nozzles have a tapered edge to give a wide angle flat spray pattern. Uniform coverage is also achieved by overlapping each nozzle 30% with the nozzle each side of it. There are also many sizes of these nozzles that can be operated under various pressures to produce a wide range of droplet sizes. The double fan nozzles also produce two spray swaths from the one nozzle so the spray can be directed into the target from two different

angles. These nozzles produce a larger droplet size than most other nozzle types when operated at the same pressure.

Air induction Nozzles



Air induction nozzles produce large air filled droplets. The air inclusion is usually by venturi action and produce large bubbly droplets. These droplets tend to shatter on impact, further distributing the smaller droplets into the canopy. The main advantage of these nozzles is to reduce drift and allow the operator to spray in windier conditions.

Spraying equipment

Hydraulic spray booms

Conventional spray booms with hydraulic nozzles are the most common method of applying chemicals. The best results are achieved when spraying in a light breeze at about 7 km/h. The wind will be beneficial by creating turbulence to assist in carrying the droplets into the crop canopy. The performance of this boom sprayer can be improved in some cropping situations by the addition of droppers. These are short lengths of semi-rigid plastic tubes attached to the boom with nozzles at the lower end and positioned between plants to direct spray from a lower angle, increasing spray penetration and coverage.



Spray boom in onion crop



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Air assist booms

There are a few main types of air assisted booms. The most common form is a conventional hydraulic spray boom with the addition of a high volume output fan mounted centrally above the boom with an air duct extending full length along both arms of the boom. The slotted outlet of the air duct produces a curtain of air adjacent to the spray nozzles.



Air assisted boom in lettuce crop

There is also the Quantum Mist™ type boom which has a series of fan heads along a mounting bar with each fan head having a number of hydraulic nozzles mounted around the outside. The fans are situated behind the nozzles and force the air down onto the target.

The droplet laden air from air assisted booms is directed into the crop canopy causing agitation of the plants and improves spray coverage on both sides of the leaves. Air assisted booms also have the potential to reduce spray drift and allow the operator to spray in conditions unsuitable for conventional booms.



Quantum Mist™ spray boom in lettuce crop

CDA sprayers

Controlled Droplet Application (CDA) is a method of spray application where 80% of all droplets produced

are within a very narrow size range, usually about 100 to 150µm. A rotating cage, inverted cone or a flat serrated disc produces droplets by means of centrifugal force when liquid is introduced at the centre of the rotating element. Most, but not all, CDA sprayers incorporate air assist as part of their design. The air stream directs spray down into the plant canopy causing turbulence that assists in achieving better overall coverage.

Knapsack sprayers

Knapsacks (or hand operated sprayers) are designed to be carried and operated manually by one person. They are suitable for treating small areas including vegetable gardens and greenhouses. These sprayers have a tank of up to 20 L capacity and are usually carried on the operators back. The nozzles used in knapsacks are the same as those used in conventional boom sprays. Often there is only one nozzle at the end of a wand but there may be more to increase water rate or spray width. Knapsacks can be pressurised by a lever operated pump, motorised pump, battery operated pump or portable compressed air. Most knapsacks sprayers operate at moderate to low pressure (200 to 400 kPa). Droplet size and flow rates can be regulated by adjusting the pressure.

Water quality

The quality of water used when spraying agricultural chemicals can have significant effects on chemical efficacy. It is always advisable to use clean rainwater where possible. This is not always possible and usually water has to be sourced from other places including bores, dams, channels and rivers. The quality of water available from these other sources can be variable and may cause significant application problems. It is preferred that the water is clear, colourless, odourless and neutral (pH 7.0). That is, not acid, alkaline or brackish. Water should be selected for the following characteristics:

Low total solids

Water from dams and rivers often contain suspended clay particles making the water look murky. Herbicides such as glyphosate and paraquat are affected by muddy water. Muddy water also causes problems by blocking nozzles. Solids in water may also contribute to nozzle wear. Organic matter (including algae) can also lead to major blockages of filters and nozzles. High levels of algae can increase the water's alkalinity.



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Neutral pH

This is the acidity or alkalinity of water, with a pH of 7.0 being considered neutral. Most water has a pH of between 6.5 and 8. Water with a pH above 8 is considered alkaline and can cause many chemicals to undergo a process called alkaline hydrolysis. This process causes the breakdown of the active ingredient into other compounds which can reduce the effectiveness of the pesticide over time. The efficacy of carbamate and organophosphate insecticides decreases sharply in alkaline water above pH 7.0. If using alkaline water cannot be avoided, it may be necessary to reduce the pH before using. Very acid water can also affect the stability and physical properties of some chemical formulations.

Low salt levels

A high salt content in water can cause phytotoxicity (damage to plant tissue e.g. burning). This is most common with bore water.

Water 'softness'

Water is termed "hard" when it has a high percentage of calcium and magnesium. Difficulty in producing a lather with soap is an indication of hard water. Hard water can cause some chemicals to precipitate resulting in reduced efficacy.

Testing water quality

You can test the quality of your water at home to see whether it will affect the performance of the chemicals you want to use. First test the pH and EC with kits or meters purchased from hardware or pool stores. You can then get a quick guide to the suitability of water by making up a sample batch. Mix up a small amount of correctly diluted spray in a clear glass container (0.5 to 2.0 L) according to the manufacturer's instructions. Shake the container vigorously for one minute and then allow it to stand for 30 minutes. If, after this time, 'creaming', sedimentation or separation into layers occurs, the water may not be suitable for spraying the particular pesticide or combination of pesticides you have tested it with. If after testing the water at home you are concerned about its suitability, you should consider sending your water away for testing. The company undertaking the test will be able to recommend improvements you can make.

Timing sprays for best results

Environmental conditions

It is important when spraying that the droplets are transferred to the correct target with minimal losses. Prevailing weather conditions may have an important

influence on the behaviour of these droplets and consequently their final resting place and efficacy in the crop.

Temperature will affect the rate of evaporation (volatilisation). High temperatures will increase the rate of volatilisation of the chemical and increase the rate of evaporation of the liquid that forms the spray droplets. Low humidity will also increase the rate of evaporation of droplets. **It is best to spray when the temperature is low and the humidity is high.** It is recommended to conduct spraying when temperatures are below 28° C and above 50% humidity.

Wind speed and wind direction also have a significant effect on spray droplets. **The ideal wind speed is a light breeze about 7 to 10 km/h (leaves and twigs are in constant motion).** A moderate breeze about 11 to 14 km/h is suitable for spraying vegetables where you are using high volumes of water (above 250 L/ha) but it is recommended that low drift nozzles are fitted. Completely still conditions should be avoided.

Pest life cycle

Spray application treatments for insect control are best applied when the pests are at their most vulnerable. This is generally when they are in their early instar or early larval stage. An example is grubs of which there are many species that are damaging in vegetable production. Unfortunately some grubs have developed resistance to many of the insecticides registered for their control. While some of these grub pests have demonstrated a high level of resistance in the later instar stages, they are still susceptible to the same insecticides while they are in the early instar stages (first and second). Also, as grubs mature, many tend to migrate to the centre of the host plant making it much more difficult to reach with spray treatments.



Heliopsis larvae enjoying sweetcorn
(Source: Sandra McDougall VIC DPI)



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Calibration

Chemicals need to be applied at the correct rate in the appropriate amount of water. To achieve this, all spraying equipment needs to be calibrated. There are many methods of calibrating with an accurate and simple method explained here.

1. Select a 'required water application rate' in L/ha
2. Determine the 'swath width' in metres
3. Calculate the driving speed
$$\frac{\text{Distance driven (m)} \times 3.6}{\text{Time taken (sec)}} = \text{km/hr}$$
4. Select the nozzle type and size to give the 'water output' required
5. Select the appropriate operating pressure from the manufactures nozzle chart
6. Determine the total 'water output' from all nozzles (L/min)
7. Calculate 'actual water application rate' in L/ha
$$\frac{600 \times \text{total flow from all nozzles (L/min)}}{\text{Swath width (m)} \times \text{tractor speed (km/hr)}} = \text{L/ha}$$
8. Compare the 'actual water application rate (step 7) to the 'required water application rate' (step 1). If the difference is too great, you will need to recalibrate. To increase the water rate per hectare, you can reduce tractor ground speed, increase pressure or select larger nozzles. To reduce the water rate you can increase tractor ground speed, reduce pressure or select smaller nozzles. It should be remembered that changing the pressure will alter the droplet size and nozzles should not be operated outside the recommendations in the manufacturer's charts.
9. Calculate how much chemical to put in the spray tank

$$\frac{\text{Recommended label rate (L or kg)} \times \text{amount of water in spray tank (L)}}{\text{'Actual water application rate (L/ha)'}}$$

Storage of chemicals

Chemical shed

Besides taking care when using pesticides, you also need to store them safely. Keep all pesticides used on the farm in an area specially designed for this purpose. Safe storage maximises the life of pesticides and protects people, animals and the environment. A farm pesticide store needs the following features:

1. It is a separate, well-ventilated cupboard or building, used only for this purpose and is preferably fireproof. It is located well away from houses, pumps, tanks, waterways and domestic animals.
2. It provides a cool, dry place that is out of direct sunlight for appropriate pesticide storage. Temperatures should be kept between 5° and 30°C.
3. It has some form of spillage containment or bunding. This bunding must be able to hold 25% of the quantity of liquid pesticide stored or a minimum of 100% of the largest container or tank stored.
4. It has shelving made of impervious material rather than something absorbent like timber.
5. It is always kept locked and clearly signposted e.g. 'Chemical Store – Keep Out' or 'Danger – Keep Out' so that everyone will know that pesticides are stored there.
6. Water for washing, a hand basin and shower are nearby for people using the store. It is also more convenient and safer to have a water supply close to the store for making up tank mixes.

Shelf life

Many products do not have an easily-identified or effective shelf life recorded on the label. If you are not sure whether a pesticide is still okay to use, call the manufacturer. Two years is considered a reasonable shelf life for most pesticides, and many will remain effective for longer if stored properly.



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Record keeping

When using chemicals on your farm you must keep a record of each pesticide application. There is no special form that needs to be used but the pesticide record needs to be made within 24 hours of application and kept for three years. It is the responsibility of the person applying the pesticide to make sure an accurate record of the application is made, however, someone else may write the record for your applications. For each pesticide application you need to record:

1. Who applied the pesticide (name, address and contact details)
2. Date and time of application
3. Product details and the amount used
4. Where the pesticide was applied (property and paddock name)
5. Order of paddock sprayed (if more than one was treated)
6. Crop or area treated (crop type or situation)
7. Application equipment used
8. Weather information (wind speed and direction)

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Horticulture Australia

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Case Study - Matthew Stott's spray application practices

Mathew Stott is a young and highly motivated farmer in the Riverina. Along with his father Richard and younger brother Andrew, they grow a range of summer and winter crops. The partnership owns 2200 ha with properties near Darlington Point and Whitton. They currently grow close to 1000 ha of summer cropping but with expected higher water allocations they are planning to increase this amount. Their main focus is producing cotton, wine grapes and popcorn. The Stott family also have a long history of growing vegetables. They have previously been large producers of tomatoes and sweet corn for processing but recently changed their focus to pumpkin, lettuce and onion seed production.



Matthew and his spray rig

Using the right equipment for the job

Mathew's philosophy for spray application is quite clear and he does not want to waste time by doing a half hearted job. When any spray application is done, he not only expects it to be done correctly, he expects it to be done quickly. To make this happen, the Stott family have purchased a new self-propelled boom spray. When the Househam boom spray was purchased it had to conform to their current bed farming system. They currently use a four bed per pass system (with their cultivating and sowing equipment) to produce 1.8m beds. Their new boom covers 16 beds in one pass (28.8m wide) and fits perfectly into this system. This setup allows them to minimise compaction as they drive along the previous wheel tracks used with other operations.

Mathew also required the nozzle spacing to match his current 1.8m bed system. The new Househam boom is fitted with two separate lines for the nozzles. Both lines are spaced at 0.45m apart which allows for the attachment of droppers if necessary. Mathew sees this as an important feature to be able to direct some of the spray below the top of the plant line. He expects efficacy will be improved when trying to control broadleaf weeds in corn or when applying insecticides or fungicide lower into the plant canopy.

Right rates

Using appropriate water rates is also a priority and Mathew has a good understanding of how much is required for all the spray operations on his farm. When spraying fallow paddocks with sprayseed he aims for 150 l/ha and can achieve this in an exceptionally quick time (at approximately 50 ha/hour) with excellent results. For his vegetable crops he uses a minimum of 250 l/ha and will increase this to 400 l/ha for more mature crops with lots of foliage to penetrate.

Mathew considers one of the best decisions they have made to their spray application operations is changing to turbo twin jets. He is very happy with these nozzles as they can get the droplet size they want with twin spray direction for better coverage. Mathew has fitted a range of different size turbo twin jets to the machine which gives him plenty of options for all his different jobs. When spraying out herbicides he uses the nozzles that gives him larger droplet sizes and reduces the chance of drift. When spraying fungicides and insecticides on his vegetable crops he uses the smaller turbo twin jets and increases the pressure to achieve a smaller droplet size. Also he has the option of operating both lines on his boom at once which gives an effective nozzle spacing of 0.225m. This allows for higher water rates at the appropriate droplet size without sacrificing operating speed.

Using clean water

Only using clean water is another important factor for Mathew. He previously used channel water for his spray operations but that is now a thing of the past and he only uses clean water from his bore. The quality of water is important as high content of dirt and organic matter leads to too many blockages. Ensuring the pH range is around the neutral level also helps to maximise the efficacy of all his chemicals. Mathew will truck in clean water for his spraying requirements before returning back to use channel water.