

# IMPROVING SPRAYING EFFICIENCY

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## 1. Introduction

Methods of improving spray deposition and reducing drift during the application of pesticides has been of concern for many years. Pesticide drift, as defined by the National Coalition on Drift Minimization, is “the physical movement of pesticide through the air at the time of pesticide application or soon thereafter from the target site to any non-target site.”

Spray drift is an important and costly problem facing growers. Drift results in damage to susceptible off target crops, environmental contamination to watercourses and an unintentionally reduced rate of application to the target crop, thus reducing the effectiveness of the pesticide. Pesticide drift also affects neighbouring properties, often leading to public outcry and conflict.

Traditional airblast sprayers direct the air from a single axial flow fan, mounted directly behind the sprayer, in an upward and outward direction, Figure 1. Axial fans are designed to move large volumes of air at low pressures, and an increase in fan diameter rather than fan speed is a more efficient way of increasing airflow rate. Traditional advice to growers was to use small adjustable deflector plates, fitted at the top and base of the air outlet to direct the air towards the target canopy in an attempt to confine it. Unfortunately many growers appear to be using sprayers with no deflectors or many manufacturers offer optional deflectors which serve little or no purpose.

The majority of growers use older, traditional design airblast sprayers fitted with hollow cone or air-shear nozzles that provide a large amount of air to penetrate the canopy and beyond, often resulting in a vast plume of spray drifting above the target row. Air-shear nozzles rely on high wind speeds (150-500 km/h) to create fine droplets, often exacerbating the drift problem, particularly when a sparse canopy exists in early season.

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**A series of workshops were held across Australia in October 2008, arranged by Drs Mark Sosnowski and Trevor Wicks of SARDI and Mr Duncan Farquar of The National Wine and Grape Industry Centre. Funding in part for this tour was kindly provided by the Grape and Wine Research and Development Corporation and Cornell University. This paper is provided as a supporting document for the workshop attendees.**

Current spray practice is often to use the same settings on the canopy sprayer in the vineyard from the first application through to the last, irrespective of changes in canopy volume or density. Many growers may change application volume/hectare but certainly no changes are made to air flow (speed, volume or direction) nor forward speed. As the season progresses, as the canopy fills, growers frequently drive too fast and often pay too little attention to deposition on the leaves and grape clusters where disease or insects may occur and to drift. The objective in improving deposition is to find the optimum combination of application parameters for different stages of canopy development to improve deposition whilst reducing drift.

Two types of drift occur during or after pesticide application: vapour drift which is the airborne movement of evaporated chemical (highly volatile materials), can occur even after the droplet is deposited on a leaf surface. The second and more prominent, droplet drift, is the movement of spray droplets in liquid form. Smaller droplets, less than 100 $\mu$ m (microns) may be projected 33 feet or more vertically. For hydraulic nozzles found on air blast sprayers, 45% of droplets may be in the 30-100 $\mu$ m size range

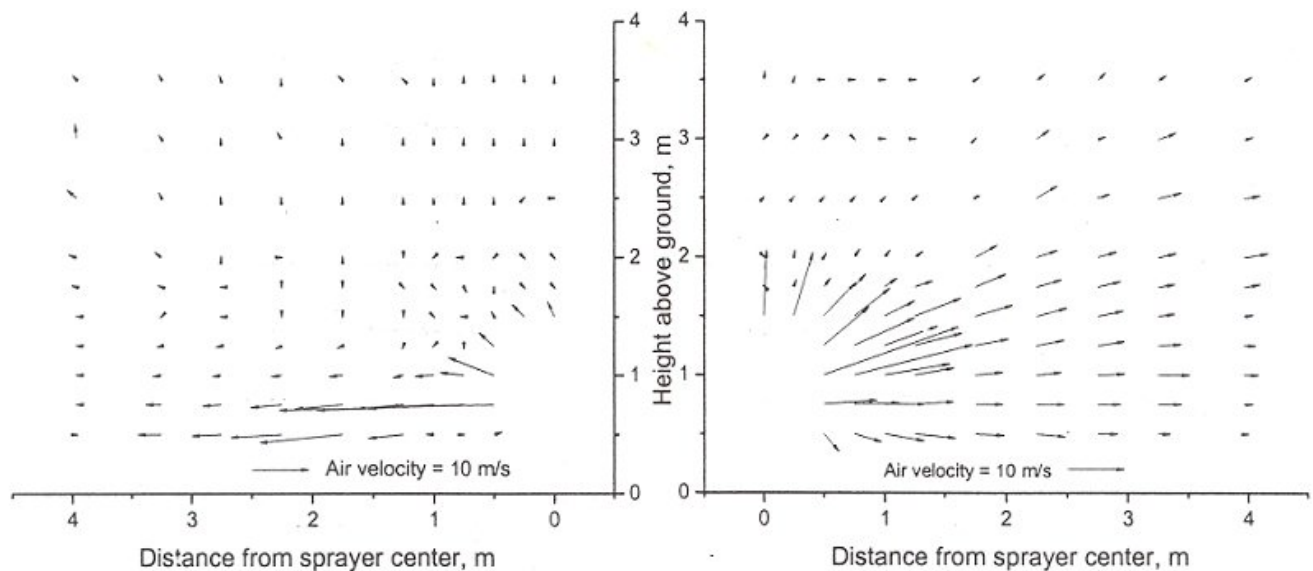


Figure 1 Air vector diagram showing air velocity and direction. Size of arrows indicate air speed

Droplets under 150 microns generally pose the greatest drift hazard; droplets less than 50 microns have insufficient momentum for impact as they remain suspended in the air indefinitely or until they evaporate. Research in England concluded that a 100 micron droplet takes 11 seconds approximately to fall three metres in still air; when a similar size droplet is released into a 8km/h wind it will drift about 23m before hitting the ground. Imagine the distance it could travel in a 290km/h airstream from some airshear sprayers! The higher the operating the pressure, the smaller the droplet, conversely, low pressure produces large droplets that may bounce off the target (droplets over 300 microns bounce). Deposition efficiencies are typically only 55% of the applied spray from an airblast sprayer, suggesting that 45% of pesticide either hits the ground contaminating the soil or goes up into the air. Much of the ground losses are spray droplets

returning to the ground from airborne drift. Depending on the canopy growth stage and season, losses occurring during spraying are:

<i>Losses</i>	<i>%</i>
Evaporation	4-6
Drift	10-15
Ground	30-50
<b>On target</b>	<b>29-56</b>

Table 1 Typical losses during spraying

<b>Sprayer</b>	<b>Application</b>	<b>Target</b>	<b>Weather</b>	<b>Operator</b>
Design	Application rate	Variety	Wind speed	Skill
Droplet size	Nozzle orientation	Canopy structure	Wind direction	Attitude
Fan size	Forward speed	Area	Temperature	
Air volume		Every row	Humidity	
Air velocity and direction		Alternate row		

Table 2. Inter-related factors affecting pesticide drift and deposition

## 2. Canopy

The vine canopy should intercept the spray plume as it passes outwards from the sprayer. The amount of droplet capture will depend on the volume, speed and direction of the spray cloud. The canopy also plays a major role during the first pre-bloom spray, in early season, when there is very little target area to capture the droplets and most of the spray passes through and is then subject to drift. Research was conducted at Cornell University using a LIPCO tunnel sprayer to measure spray retention in the canopy over the growing season. The LIPCO uses a recycling feature, any spray not captured in the canopy is recycled. The quantity being recycled was measured and in early season (May 22<sup>nd</sup>) shows that *var.* Cabernet Franc and Riesling canopies required only 170 litres/ha. In mid July the full canopy retained 500 litres /ha. Research in Spain, shows that early season losses to drift and ground deposition can be as high as 45%, depending on the volume applied, the variety and canopy development.

One of the major areas of concern is alternate row spraying in early season. Many growers have observed a large spray plume going past the target row, onto the second and third rows. As they are under pressure to improve their timeliness, they choose to spray alternate rows. When a disease outbreak occurs, questions are raised! Our research shows that sometimes the sprayer is calibrated for say 500 litres/ha, but growers frequently forget that it was calibrated for single row spacing at 2.8m. Driving alternate rows results in only 250 litres/ha per acre being applied,

frequently via a badly set-up sprayer, the result: disease outbreak. Results indicate very erratic deposition on the second row, particularly in early season canopies as the wind going across the vineyard can affect the spray plume, Figure 2 compares alternate row to every row application.

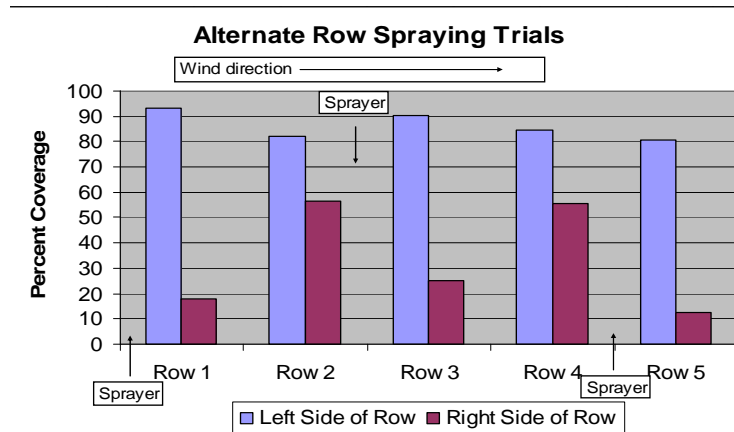


Figure 2 Erratic deposition in early season using alternate row spraying

### 3. Climatic conditions

The weather plays a critical role in drift management. Wind velocity, relative humidity, and temperature all affect the characteristics of the spray plume. As wind speeds increase, spray droplets will drift farther. Humidity and temperature determine how fast the spray will evaporate. A higher temperature means the droplets are more apt to dissipate and in some cases vaporize completely. At lower humidity, evaporation occurs much faster. Larger droplets, >200 microns, are affected the least due to their shorter travel times, but may still evaporate after depositing on the canopy. Atmospheric inversion is another problematic condition, when the temperature, instead of decreasing, rises with altitude. With cooler air at lower altitudes there is no tendency to form upward air currents, causing drifting pesticide droplets to become easily trapped. Spraying in ideal, neutral conditions greatly reduces the effects of drift.

Droplet size is important in determining the amount of drift in conjunction with the wind, temperature and relative humidity. The size of a droplet strongly influences its trajectory after being emitted from a hydraulic nozzle at a speeds of 70-110 km/h. Training the operator to recognize conditions which lead to excessive drift such as high winds, fine spray, inversion layers etc. is so important. Temperature affects spray droplet movement.

#### *Unstable conditions – do not spray*

Warm air is lighter than cold air so rises, an example of this is in the afternoon on a sunny day when the vineyards are warm, the air near the ground warms up and wants to rise up towards the cooler air above, this is referred to as an unstable surface layer. Air rises and mixes with the air above carrying pesticide particles with it.

#### *Stable conditions – do not spray*

At night the vineyard land gives up its heat rapidly (radiant cooling), the air nearest the vineyard is cold, and being heavier than the warm air above it remains close to the ground, this is referred to as a stable surface layer or temperature inversion. The cold air is unable to mix with the warm air above, causing small suspended droplets to form a concentrated cloud which can lead to long distance migration of pesticide drift, for several miles. Clear skies favour radiant cooling, and therefore favour inversion layers, this can occur in early morning and late afternoon.

#### *Neutral conditions – spray*

Cloudy skies, moderate to strong winds, i.e in excess of 4.5 km/h and bright sunshine are all conditions which don't favour inversions and are referred to as neutral conditions.

Sprayer operators can notice changes in the weather as the day progresses, often you can tell if an inversion layer is forming by watching smoke rise, if an inversion layer is present the smoke rises vertically for a short period and then turns, moving horizontally.

## **4. Barriers to drift**

#### *Buffer zones*

In an ideal world, growers should avoid planting grapevines too close to neighbouring properties and water courses. A good, safe buffer zone should be between 15 to 45 metres, but the distance required will depend on the type of buffer zone, type of sprayer being used, toxicity of the pesticides, trellis design, and prevailing wind direction. Buffer zones are usually located on the downwind side of the vineyard.

German buffer zones are amongst the severest in Europe and are worthy of note. Since 1996 they have developed buffer zones and use a system described as the Drift potential index (DXI) to take into account local conditions such as water and vegetation. As far as grape vines are concerned they have measured drift values up 40 -50 metres.

#### *Shelter belts*

Augmenting the buffer zone with a natural or artificial shelterbelt is an effective means of further reducing drift, and also provides some visual-screening of vineyard operations. The primary purpose of a shelter belt or wind-break is to reduce wind flow across the vineyard, reducing drift from the vineyard and in some cases allowing the spraying operation to continue when it would be impossible on a more exposed site.

Windbreak height and porosity affect effectiveness, a porous buffer which slows air movement but does not redirect it up an over will remove more spray droplets than will a solid wall of vegetation. As a general guideline, this "scrubbed layer" extends to a distance of approximately 3 to 10 times the height of the barrier. The minimum height of the shelter belt should be at least double the release height of the pesticide e.g. a poorly directed air-blast sprayer shooting a spray plume 6 metres into the air will require a tree barrier of at least 15 metres high. Mixed plantings

of trees, with thin rough foliage and small hairy leaves are best for providing a porous barrier for collecting the spray.

## **5. Improving existing application techniques to improve deposition**

### *1. Weather monitoring equipment.*

Growers should purchase and use good quality instruments for measuring wind speed, temperature and humidity. Small, hand held anemometers cost around \$100 and provide fairly accurate information on wind speed. Spraying with no wind present is dangerous due to potential problems with vapourisation and inversion layer conditions, similarly, spraying when wind conditions are too high is equally dangerous.

### *2. Sprayer check*

One of the simplest ways to help reduce drift is to maintain and calibrate the sprayer, equipment should be maintained and operated according to manufacturer's instructions. A well trained operator will notice a spray plume drifting away as windspeed increases or changes direction. Choice of nozzle can affect drift by governing particle size, select low drift nozzles that minimize the number of drift prone fine droplets less than 150 microns. Replacing worn nozzles when they exceed the manufacturers flow rate by 10% and matching the correct nozzle to the type of application is a fairly inexpensive practice to help reduce drift.

### **Example of a 40 ha vineyard**

\$600/ha in pesticide costs

Sprayer with 10 nozzles in total

$\$600/10 = \$60 / \text{nozzle} / \text{ha}$

$\$60 \times 40 \text{ ha} = \$2400$  in pesticide cost per nozzle

Cost of an individual nozzle: \$10 - 20

### *3. Nozzle orientation*

Orientation of the nozzles affects the spray pattern being emitted from an air blast sprayer. Traditionally growers have positioned nozzles radially around the air outlet of the sprayer. The direction of the airstream, on a sprayer with a counter-clockwise rotating fan, carries the droplets upwards, over the canopy on the right-hand side of the sprayer, and predominately downwards on the left-hand side. Where the air flows the droplets will surely follow. At Cornell University an Italian vertical tray patternator (Mibo, Milano, Italy), is used to simulate the canopy at the center of the vine row. The patternator comprises a series of collecting trays which are situated at 16 inch intervals above the ground, the sprayer is turned on and the water plume collects in the trays. Water then runs down pipes into a row of measuring cylinders, indicating the spray profile or vertical distribution pattern. Different nozzle configurations (number and orientation) are selected and vertical spray patterns determined.

Results from the patternator, figures 3 and 4, shows not only the great variability in spray pattern produced according to nozzle orientation but also the lack of symmetry between each side of the sprayer. Note 33% of the spray was overshooting the canopy before a change in nozzle orientation was made. On the Berthoud S600EX sprayer used as an example, nozzles set

in the “typical growers” pattern, Figure 3, pointing radially outwards, resulting in a large quantity of spray being blown above the target row. The best spray pattern for the grape zone, Figure 4, occurred when the right hand side nozzles were pointing horizontally and the top two nozzles were 20° below horizontal on the right side, to counteract the upward movement of the air from the fan. Best results occurred with the left side nozzles pointing 45° upwards to counteract the downward direction of the air from the fan. The results show the importance of correct nozzle orientation if pesticides are to be applied effectively onto the target.

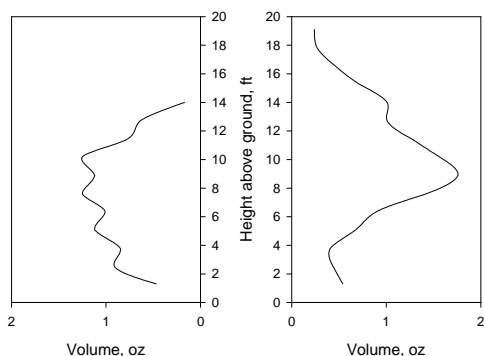


Figure 3. Original nozzle setting

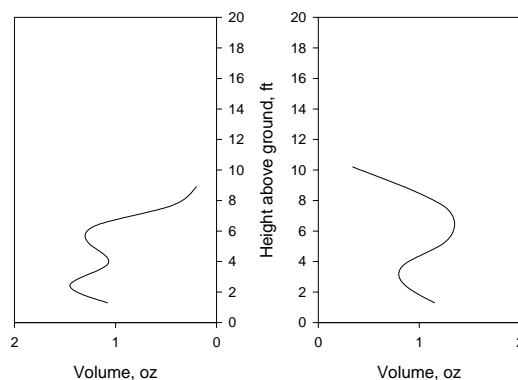


Figure 4. Improved nozzle setting

NOTE: Results shown are for a Berthoud S600EX sprayer, individual sprayer models will vary.

An inexpensive and simple patternator may be constructed on the farm using fly screens, similar to those found on windows. A detailed build list and photographs maybe found on my web page at <http://www.nysaes.cornell.edu/ent/faculty/landers/pdf/Patternator.pdf>

To see where the spray is actually going in the vineyard, a grower can create a simple system to check the spray plume. One method is to use a 5m high, 25 mm wide wooden pole with paper tape (commonly found in cash registers or office calculators) stapled along the leading edge. Place the pole between two vines within the row, attach it to the trellis wire using plastic ties and spray a mixture of clean water and food colouring. Travel between the rows, spraying out the mixture. The spray will stain the paper where it hits. By looking at the coloured spray droplets on the paper, the grower can alter the orientation of the nozzles, fans or deflectors until the spray cloud is only hitting the portion of the vertical pole/vines that is desirable. Double check the spray output with a new piece of paper tape following each alteration of the operating parameters.

**4.** *Air Induction Nozzles (AI).* These nozzles, when used properly, can reduce drift by at least 50 percent. The principle behind these nozzles is to create a larger droplet that won't drift as far but still maintain good leaf and fruit coverage. Air induction (A.I) nozzles are available either as flat fan or hollow cone nozzles where an internal venturi creates negative pressure inside the nozzle body. Air is drawn into the nozzle through one or two holes in the nozzle side, mixing with the spray liquid. Figure 5 shows the results of a drift comparison trial at Cornell University, where a Berthoud trailed airblast sprayer was fitted with flat fan air induction nozzles and compared to the same sprayer fitted with hollow cone nozzles.

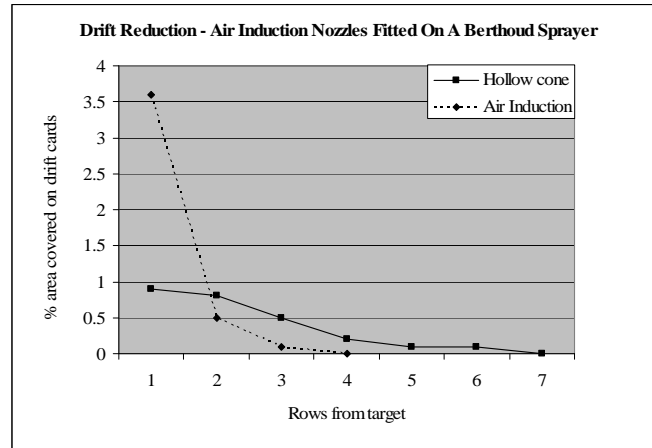


Figure 5. Drift reduction using air induction nozzles

## 5. Regulating air speed.

### *PTO speed*

Regulating the PTO speed of the tractor is an inexpensive way to reduce drift. Traditional airblast sprayers direct the air from a single, axial flow fan, mounted directly behind the sprayer in an upward and outward direction. Where the air goes, the droplets will surely follow. Early – mid season sprays are frequently applied at full fan speed, resulting in a mighty plume of pesticide going towards a small leaf target on a small vine or up into the air above the vineyard. Is it necessary to have the fan rotating at all or even rotating at very slow speed? Do we really need to use an airblast sprayer creating up to 50,000 cubic metres of air/hour at airspeeds of up to 300 km/h when our leaf target is only a few millimetres long in early season?

In trials at Cornell University, Table 3, with an airshear type sprayer (AgTec), drift was detected on water sensitive cards fitted to 4m tall drift poles, placed at 6m intervals up to 24m from the target row. When the tractor PTO speed was reduced by 25%, drift was reduced by 75%. The reduced air speed also increased droplet size (due to the operating characteristics of air shear nozzles), further reducing the effects of drift. Reducing PTO speed with a conventional airblast sprayer will have a similar effect.

### *Hydraulic Drive*

Using a hydraulic motor to drive the sprayer fan will allow the operator to regulate wind velocity. A hydraulic control valve can be fitted in the tractor cab to allow the operator to infinitely vary the fan input speed from 0 rpm up to 540 rpm. The operator can reduce air speed during early to mid season applications and increase it for full canopy applications. When approaching the end of a block of vines, near neighbouring properties, drift-sensitive crops, roads or water courses the operator can easily adjust the airflow and therefore reduce the spray plume. Care should be taken to ensure the tractor has a high enough oil flow (gallons/minute) to drive the hydraulic motor at speed.



Tractor <sup>1</sup> PTO Speed, rpm	Sprayer Fan Speed, rpm	Drift pole 1	Drift pole2	Drift pole 3	Drift pole 4
<b>Spray Coverage, %</b>					
540 <sup>2</sup>	2076	75.90	69.00	16.60	10.10
405 <sup>3</sup>	1557	16.70	0.20	0.10	0.04

**Key:**

Each drift pole is located 6m from the target row

- 1 John Deere 5520 tractor
- 2 Mean wind was 5.5 mph coming from NW with gusts of 10.5 mph
- 3 Mean wind was 7.7 mph coming from NW with gusts of 12.5 mph

Table 3. The effect of fan speed on spray drift from an Ag Tec sprayer

*Cornell Doughnuts*

These attachments restrict air intake and therefore reduce air flow through the airblast sprayer. A simple plywood doughnut can be constructed using a jig saw and attached to the sprayer air intake using bolts. The diameter of the intake is measured and a hole created in the centre of the plywood circle. Remember to ensure a safety grill is fitted to prevent fingers from entering the fan. For early season, a 1/2 diameter air intake doughnut can be used, allowing just enough air to penetrate just the target row. A 2/3<sup>rd</sup> air intake hole can be used for early/mid-season to allow more air to flow. Finally in a full canopy, no doughnut is required. Results of trials indicate excellent drift reduction from a simple yet effective device.

**6. Directing airflow**

*Tower sprayers, deflectors and multi-fan sprayers*

Tower sprayers and deflectors are better at reducing drift and targeting the spray into the canopy than a conventional airblast. The conventional air blast sprayer sends droplets in an air blast from a central fan upwards and outwards into the canopy whereas the addition of a tower or deflectors creates a horizontal air curtain. In some cases the horizontal airflow can be adjusted via internal deflectors to direct the air e.g. towards the fruiting zone. A number of manufacturers sell “grape towers” as a retrofit to existing airblast sprayers

***Directed air ducts***

A number of sprayers direct the air to the target via adjustable outlets mounted around the canopy, e.g. Silvan and Hardi SPV. Each outlet incorporates a hydraulic or air shear nozzle surrounded in a stream of air. The outlets may be mounted on either side of the sprayer or fitted to a frame or gantry allowing two to three rows to be sprayed. Outlet angle is adjustable, depending upon growth stage, shape and density of the canopy. The converging air stream

provides good leaf turbulence resulting in excellent penetration with minimum drift. Growers are encouraged to alter the angle of the air outlets, e.g. in early season use the lower outlets only for spray and place the upper units in a horizontal plane to create an air blanket over the row, thus keeping the droplets within the canopy.

### ***Tangential blowers***

A few sprayers are available which use a hydraulically driven tangential or cross flow fan to blow air radially into the canopy. A line of hydraulic nozzles or spinning discs produce droplets which are then carried by the airstream. The position of the fans is adjustable, allowing a more directed spray plume than from a traditional airblast sprayer.

### ***Multi-head fans***

These sprayers, such as , Croplands Quantum Mist and Greentech use small axial fans to create a directed airblast, either driven by hydraulic or electric motors, in front of each small fan are hydraulic nozzles. Hydraulic nozzle versions allow operators to change droplet size by changing nozzle size or system pressure. The fans should be adjusted so that they are not directly opposite each other (remember cymbals clash and air will move upwards and downwards) so adjustments should be made so that the fans are facing at least 5-10degrees backwards. In early season check the effect of only two diagonally opposed fans in operation, rather than using all four fans. Manufacturers are encouraged to fit fan speed controllers in the tractor cab to allow operators to adjust fan speed as conditions vary.

## **7. Axial fan size, speed and air induction nozzles**

Using an axial fan producing 20,000m<sup>3</sup>/hr and in conjunction with air induction nozzles will result in a 75 percent reduction of drift. In order to accommodate varying crop canopies, e.g as the season progresses, a number of modern sprayers are fitted with adjustable pitch propellers to provide a variable airflow. Operators can manually adjust blade pitch either by turning a handle or altering individual blades. Growers should assess air volume requirements by observing spray penetration into the canopy and the amount of spray going up and over or through the canopy.

## **8. Foliage Sensors**

These sensors, either operating with infra red or ultra-sonics detect the absence or presence of a vine or canopy. Each sensor fires a ray of light or sound towards the canopy, any resulting reflection, due to the presence of vines or canopy, is picked up by the sensor and automatically opens or closes a valve near the nozzle(s) allowing spray to be emitted or switched off. The use of sensors reduces overspray of the canopy and can reduce drift by 50 percent, they also cut down on the amount of pesticide being used. They are relatively expensive in the USA (not so in Europe!).

## **9. Tunnel Sprayers**

The LIPCO tunnel sprayer comprises a plastic tunnel mounted onto a frame, the tunnel surrounds the grapevine. Mounted on the inside the tunnel walls are two vertical spray-booms fitted with hollow cone or flat fan nozzles which direct spray horizontally, into the grape canopy. Any excess spray is runs down the inside of the tunnel wall and is collected in a trough at the base of the tunnel where it is recycled back to the main tank. In early season trials, up to 75% of spray

was recycled, at full canopy very little recycling occurs but average reduction in pesticide use amounts to 35% over the season. Research conducted at The Federal Biological Research Centre for Agriculture and Forestry (BBA) at Braunschweig, Germany, shows that the tunnel sprayer reduces drift by 90% and, when air induction nozzles are fitted, reduces drift by 99%. Tunnel sprayers were developed as long as 50 years ago are becoming very popular and will continue to do so. Modern construction using lightweight plastic or glass-fibre and well-designed hitches allows a fair degree of maneuverability. Their major success is in reducing the visual effect when compared to the large plume created by other sprayers, helping reduce public perception of pesticide application.

## **10. Drift reducing additives**

A number of manufacturers supply drift reducing agents, most work via increasing droplet size (larger droplets don't drift). Beware not all of them can withstand the higher pressures associated with fruit sprayers and interestingly often create more drift than without agents. Growers should seek independent verification of the effectiveness of drift reducing additives, rather than accept the advice from the company sales person!

## **11. Nozzle selection**

Remember that large droplets, over 300 microns bounce and small droplets, less than 150 microns are drift-prone. Remember the effect on droplet size of using old and or damaged nozzles. Clear blocked nozzle tips using compressed air or an old toothbrush. NEVER kiss nozzles.

As a guide, select nozzles based upon the selected target, using spray quality charts found in modern nozzle catalogues.

Target: Insects/ disease on foliage, contact sprays: FINE spray quality

Target: Foliage, herbicides and systemic products :MEDIUM spray quality

Target: Soil, pre-emergent herbicides: COARSE spray quality

## **12. Monitoring the effectiveness of the sprayer in the vineyard.**

Check to see the effect of changes you have made to your application methods. Use Kaolin clay products such as "Surround" to see deposition in daylight, it is safe and inexpensive. An alternative is to use fluorescent tracers but double check that they are "food safe" and approved for such use; use them at night. Remember the boundary layer effect of airflow on a body so look at many samples, particularly in the fruit zone.

An alternative to purchasing expensive water sensitive cards is to use food colouring and photographic quality paper cut into 25mm x 50mm strips, stapled over the leaves.

## **13. Calibration**

Remember to calibrate the sprayer, check individual nozzle output and replace nozzles whose output exceeds 10% of the catalogue value. A particularly good calibration method is described on You Tube via the internet:-

Calibration of airblast sprayers for vineyards - Part 1 Selecting and changing nozzles  
Calibration of airblast sprayers for vineyards -Part 2 Measuring nozzle flow

## **Conclusions**

Drift is impossible to eliminate but can be minimized. Implementing some of the above methods will improve the efficiency of the spray application saving time, money, and future problems.

1. Good operator training on the causes of drift, recognizing when weather conditions change and how to take avoiding action will help.
2. Good machinery and operator management, as always, will improve deposition and reduce drift problems.
3. Changing nozzle orientation to match canopy development will pay dividends.
4. Build a patternator to see where the spray is going.
5. Use tracers to monitor deposition within the canopy following changes in sprayer operating parameters.