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Prevention Is Better Than Cure - Reducing Drift from Vineyard Sprayers

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Abstract

Penetration and drift are primarily based on the crop target, sprayer, weather and the operator. This paper discusses research results on methods to match air volume, speed and direction with increasing crop canopy and thereby reduce drift. Air volume and speed was effectively altered using restrictors and a variable speed drive provides a simple yet effective method of reducing drift. Correct orientation of the nozzles is crucial if pesticide is to be targeted correctly. The paper also describes comparative field research trials between directed deposition sprayers and airblast sprayers in vineyards. Directed deposition sprayers will improve deposition and reduce drift, only if a good target canopy exists.

Introduction

Commercial grape juice and wine production occurs in every state within the United States of America. The vineyard area has increased by 33% in the last twenty years to a total of 384,850 hectares.

The application of pesticides has been of concern for many years, particularly methods of reducing drift and improving deposition. The majority of growers use traditional airblast sprayers fitted with hollow cone or air shear nozzles. In the USA a small number of novel sprayers which direct pesticide-laden air into the canopy have been developed in the past decade (Landers 2000, Landers et al 2001). Sprayer manufacturers appear to have conducted very little research into airflow characteristics to improve directed deposition from a traditional airblast design whereas many European manufacturers have developed sprayers to direct airflow into the canopy. Many growers choose not to replace mechanically reliable sprayers and so a large number of vineyard sprayers are in excess of ten years old.

Landers (2002a) observed that spray drift is an important and costly problem facing grape 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. As more people choose to live in the picturesque setting of a vineyard or orchard and growers continue to convert farmland to housing to increase their revenue, so the debate will continue.

Traditional airblast sprayers direct the air from a single axial flow fan, mounted directly behind the sprayer, in an upward and outward direction. Axial fans are designed to move large volumes of air at low pressures. Landers (2002b) observed that in order to accommodate varying crop canopies, e.g. as the season progresses, many modern sprayers are fitted with adjustable pitch propellers to provide variable airflows. Traditional advice to growers has been to use an adjustable deflector plate, fitted at the top and base of the air outlet to direct the air towards, and confine it to the target canopy. Unfortunately many growers appear to be using sprayers with no deflectors or many manufacturers offer optional deflectors which serve little or no purpose.

Hislop (1991), in his review of air-assisted spraying, suggests the first simple air assisted sprayer was developed in France for the application of Bordeaux mixture to vines in 1885, the airstream being developed by a set of bellows. In the early 1940's axial fans were introduced in the USA and Brann (1956) concluded his review by stating we cannot go on solving the problems by building larger machines with a greater amount of airblast. Progress lies in the direction of more efficient application

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of power through a better understanding of the factors involved in getting the toxicant from the tank to the plants.

Graham (1987) states that smaller droplets (<100µm) may be projected 10m or more vertically. For hydraulic nozzles found on air blast sprayers, 45% may be in the 30-100µm size range. Deposition efficiencies are typically only 55% of the applied spray from an airblast sprayer, Reichard et al (1979), suggesting that 45% of pesticide either hits the ground contaminating the soil or goes up into the air.

Research into forced airflow and spray distribution to optimize deposition and minimize drift in a changing canopy size has resulted in the development of mathematical models. Walklate et al (2000) developed a spray dispersion model to consider the interaction of crop and spray droplets based on field trials with a light detection and range (LIDAR) system.

Sprayer design and drift

There are many inter-related factors affecting drift and deposition in vineyards.

Sprayer	Application	Target	Weather	Operator
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 1. Inter-related factors affecting pesticide drift and deposition

Even when sprayers are calibrated regularly their accuracy cannot always be relied on. Across the world surveys of the mechanical condition and the accuracy of sprayers show that many sprayers leave much to be desired. A combination of inaccurate speeds, worn nozzles, unsuitable filters and inaccurate gauges caused the problems. Survey and clinic results show how badly maintained many sprayers are on farms and how their operators require training. Education via information sheets and instruction, coupled with extension demonstrations, has addressed part of this problem but time shows very little improvement in the condition of farm crop sprayers. Mandatory sprayer testing, currently found in 13 western European countries will undoubtedly improve the standard of sprayer performance.

The principal involved in traditional vineyard spraying is to create enough air from the airblast sprayer to shift and replace the air within the canopy with pesticide-laden air from the sprayer. The leaves have a tendency to shingle in the airflow thus reducing good airflow. Vine canopy varies along the row, sometimes vines are absent presenting no resistance to air movement, resulting in air traveling through the row. When applying pesticides growers know that small or fine/medium droplets give the best coverage, as large droplets (in excess of 300 µm) will run off the leaf onto the ground. Good coverage is critical for all contact pesticides.

Spray drift

Ganzelmeier (1993), gives a good definition of direct drift as being that part of the amount of active ingredient applied, which, during the application process, is borne beyond the treated area due to atmospherical currents (horizontal and vertical) and settles outside that area (ground sediment) or is driven as solid or liquid particles in suspension, over longer distances (atmospherical drift).

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Hall (2002) suggests that two types of drift can be observed: 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.

Airblast sprayers, as used in vineyards are much more likely to create pesticide drift than the boom sprayers used on field crops. Ganzelmeier (1999) suggests that the ratios of drift (related to field sprayers) occurring with current sprayers are rated as field crops/vineyards/fruit crops/hops as 1/6/15/25. Unfortunately most published research on long distance drift is based on products used in boom sprayers.

The Spray Drift Task Force (1998) measured the droplet size spectrum from airblast and mist blower (Ag Tech) classes of sprayer. The Volume Median Diameter (VMD) ranged from 138-210 μm from the airblast and 73-110 μm from the mistblower. VMD is the droplet diameter at which half of the spray volume is composed of larger droplets and half is composed of smaller droplets. The % droplets <141 μm ranged from 26-52% for the airblast and 65-90% for the mist blower. Both the VMD and % volume <141 μm confirm that the mist blower produces finer droplets and a higher volume of drift prone droplets.

What happens to those droplets which are sent skywards in an airstream in excess of 80km/h? The size of a droplet strongly influences its trajectory after being emitted from a hydraulic nozzle at a speed of 70-120 km/h. The droplet rapidly decelerates due to friction until it attains a velocity that is solely a function of its diameter. Air movement in which the droplet descends also influences its trajectory.

Depending upon environmental conditions, drifting droplets will become smaller as temperature and humidity affects droplet size. Wilkinson et al (1998) shows that as temperature rises, coupled with low humidity, droplets decrease in size due to evaporation. In laboratory conditions, where a single droplet is released 1 metre above the ground, evaporation of fine droplets occurred above 25°C at 60% humidity. On a typical spraying day, high temperatures and low humidity can result in fine drifting droplets becoming smaller and drifting further afield.

Kurst (1990) states in the preface to his book “the transport of contaminants throughout the world has become increasingly important as we are discovering the limits of the world to absorb and digest the wastes of human endeavors.” The effects of acid rain can be clearly seen many miles from its source, the nuclear fallout at Chernobyl carried for thousands of miles. Chlorofluorocarbons have devastating effects on the stratosphere. DDT was found in Antarctica in 1965 but never used there. Marine life, found in the oceans and lakes of the world, are being detected with pesticides in their system.

According to Edwards (1973), the first suggestion that organochlorine residues maybe transported long distances in the air was by Tarrant and Tatton (1968), who monitored dust samples taken from the air in the north east tradewinds. Risebrough et al (1968), found appreciable quantities of DDT and dieldrin in dust particles from the air over Barbados ($7.8 \times 10^{14} \text{ g/m}^3$) which presumably had been carried over several thousand miles of ocean by the North East trade winds. Once airborne pesticide particles can be carried by the wind and deposited by a dry or wet (rain or snow) deposition process.

A traditional airblast sprayer sends air upwards above the canopy, carrying with it a plume of pesticide droplets. Unfortunately small or fine droplets will drift if they don't become attached to the target leaf, insect or grape. Directed deposition is needed if pesticide is to be applied to the target zone. For example disease and insect activity is often found throughout the vine canopy and sometimes certain insecticides need to be applied to the grape berries.

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Materials and Methods

Air volume and velocity

As part of an on-going project on optimizing spray penetration and deposition with air-blast sprayers, (Landers and Farooq 2004, Farooq and Landers 2004), attachments were developed to change the airflow and velocity of the sprayers that do not have an option to change fan speed. A set of wooden “doughnuts” was developed to alter the airflow of a Berthoud S600EX sprayer (Berthoud, Cedex, France). The sprayer has a 61 cm diameter axial-flow fan operated through the tractor power-take-off. The fan intake is behind the sprayer and it discharges radially between the tank and fan. The “doughnuts” reduce the air intake to 2/3, 1/2, and 1/3 at the center of the fan. Air volume was determined by measuring air velocity 15 cm away from the fan outlet and at 8 locations along the periphery. The velocity was measured using an ultrasonic anemometer (model R3-50, Gill Industries Ltd, Hampshire, UK). The air volume from these measurements was determined to be 19383, 19671, 18769, and 17174 m³/h for no, 2/3, 1/2, and 1/3 doughnuts, respectively. Velocity of the air at two sides of the sprayer for four fan intake openings was also measured at 77-point grid spread 3.5 m to horizontal from fan center and 3.5 m above ground.

The effect of air velocity on deposition in a vineyard was studied at New York State Agricultural Experiment Station Research Farm in Geneva during 2003. The vineyard had a row spacing of 2.7 m and plant spacing of 2.1 m. The vines were sprayed from two sides with four air volume rates using the right-hand side of the sprayer on three different days through the growing season. It was equipped with 5 Berthoud #10 discs and was operated at 4.8 km h⁻¹ to obtain an application rate of 468 L/ha. Water sensitive cards on upper and lower side of five leaves from 3 vines in each plot were used for coverage assessment on each side of the vines. Coverage on the cards was determined using HP 6200C scanner and WRK Droplet scan image program (WRK, Cabot, AR).

Nozzle type

A field trial to demonstrate drift reduction by changing droplet size was described by Landers (2000). Two sprayers, a Durand-Wayland Streamliner, fitted with hollow cone nozzles (D4 discs and no. 25 swirl plates) and a Kinkelder sprayer fitted with airshear nozzles were used in these trials. Air induction nozzles use a small venturi to draw in air as the liquid passes through the nozzle. The resulting droplets contain air bubbles. The large droplets, 455 microns VMD, don't bounce off the leaves as the entrained air bubbles absorb the shock of the droplets hitting the leaves.

The sprayers were fitted with air induction nozzles on one side of the sprayer and wind shear or hollow cone on the other side. The Durand-Wayland sprayer was fitted with five A/I 110-025-VS (Spraying Systems) air inclusion nozzles, operating at 345kPa. The Kinkelder sprayer was fitted with six A/I 110-03-VS (Spraying Systems) air inclusion nozzles operating at 207 kPa.

All the sprayers in all the trials used the same application rate of 463 l/ha, traveling at 5.0–5.5 km/h and were calibrated before use.

Drift was measured in all the trials by placing water sensitive paper cards, 50mm by 25mm (Spraying Systems) on collecting trays located on the top of the canopy of each row. Four collecting trays, each holding two cards, were placed at 10m intervals along the row. Collecting trays were placed on 8 rows from the target row. The cards were allowed to dry and were collected post application. The cards were placed on a HP 6200C desktop scanner and the images were analysed using a WRK Dropletscan image program. The image analysis program was used to quantify droplet size and % area covered.

Nozzle orientation

The orientation of the nozzles will affect the spray pattern being emitted from the air blast sprayer. The nozzle orientation must take into account the upward and downward air movement created by the counter clockwise direction of the fan. A vertical patternator (Mibo, Milano, Italy) was used to measure spray liquid emitting from a Berthoud S600EX sprayer (Berthoud, Cedex, France) fitted with

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5 Berthoud #10 discs on the left and right hand side. Nozzle orientation was altered to find the optimum spray pattern for the grape target zone.

Novel sprayers

A number of novel sprayers have been developed in the past decade and a number of field trials were set up to evaluate the efficiency and effectiveness at improving deposition, reducing drift and reducing disease and insect damage in vineyards in New York and Pennsylvania.

1. The Proptec, manufactured by Ledebuhr Industries of Michigan USA, uses a rotary cage to create droplets which can be directed into the crop canopy. Liquid is fed into a high-speed spinning cage then centrifugal forces spread the liquid and throw it from the periphery. Fitting the units to a boom and driving the rotary cage with a hydraulic motor provides the centrifugal force. The majority of droplets, (95% approximately), are the same size, depending upon flow rate and cage speed. A small propeller provides air movement and the position of the unit on the boom dictates air direction. A Proptec mounted sprayer was fitted with a flow regulator plate no. 89 and operated at 1.4bar and applied pesticides at 233 and 467 l/ha.
2. The ESS electrostatic sprayer is manufactured by ESS of Watkinsville, Georgia and uses an induction charging nozzle to apply a negative electrostatic charge to the droplets. The fine droplets are propelled towards the plant by a low pressure air stream. The small droplets, around 50 μm are attracted to the positive charge of the plant (opposites attract). The sprayer uses very low application rates, 84 l/ha was applied in our trials at 2 bar air pressure and liquid pressure.
3. Tunnel sprayers, developed as long as 50 years ago, are becoming very popular and will continue to do so. The LIPCO from Germany reduces drift by 90% and, when used in the recycle mode, can reduce pesticide use by an average of 30%. Modern construction using lightweight plastics 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 an airblast sprayer, this helps reduce public perception of pesticide application. A trial at the Cornell University Grape Research Station, Fredonia compared a tunnel sprayer fitted with/without a fan with their traditional high volume/high pressure sprayer on the native American variety, Concord .
4. The Italian CIMA sprayer uses multiple outlets to direct the air and spray towards the canopy. Individual outlets can be moved into various positions and upper and lower units can be operated. Trials were conducted to compare an airblast at 934 l/ha with a CIMA at 934 l/ha and 467 l/ha. Another trial compared the use of upper and lower applicators with lower applicators only.

All sprayers were calibrated before use and used in commercial vineyards were used for the trials. A seasonal spray program, chosen by the vineyard manger to balance the need for economy and control, was applied to all vines at each particular site. Sites were chosen across New York, plantings of *V. labrusca* 'Niagra' as well as *Vitis* interspecific hybrid cultivars. Within each trial, treatments were imposed in a randomised complete block design with three replications.

Drift was measured in all the sprayer trials by placing water sensitive paper cards, 50mm x 25 mm (Spraying Systems) on collecting trays located on the top of the canopy of each row. Four collecting trays, each holding two cards, were placed at 10m intervals along the row. Collecting trays were placed on 8 rows from the target row. Each sprayer was filled with clean water and passed the target row applying water at 467 l/ha. The cards were allowed to dry, and placed on a HP 6200C desktop scanner and the images were analysed using a WRK Dropletscan image program. The image analysis program was used to quantify droplet size and % area covered.

Results and Discussion

Air volume and velocity

The resulting velocity patterns are presented as Figure 1. From these patterns, it is clear that on the left side, the peak of the air stream center moves down with increasing distance away from sprayer center. The rate of descent increases with decreasing air intake, resulting in relatively low velocities in the spray target zone on the left of the sprayer compared to the right side. On the right side, the general trend showed a slightly rising stream due to the counter-clockwise direction of the fan. The air velocity on both sides was highest without a doughnut, velocity decreasing when decreasing the air intake. With the help of air velocity patterns it was found that at 1.0 m from sprayer center (\cong edge of vine canopy) and between heights of 1.25 to 2.25 m (\cong target canopy in grapes), the left side of the sprayer delivered air at < 4.0 m/s with all air intakes. For right hand side, this velocity ranged from 4-12, 4-8, 4-8, and 4-6 m/s with full, 2/3, 1/2, and 1/3 of the intake, respectively.

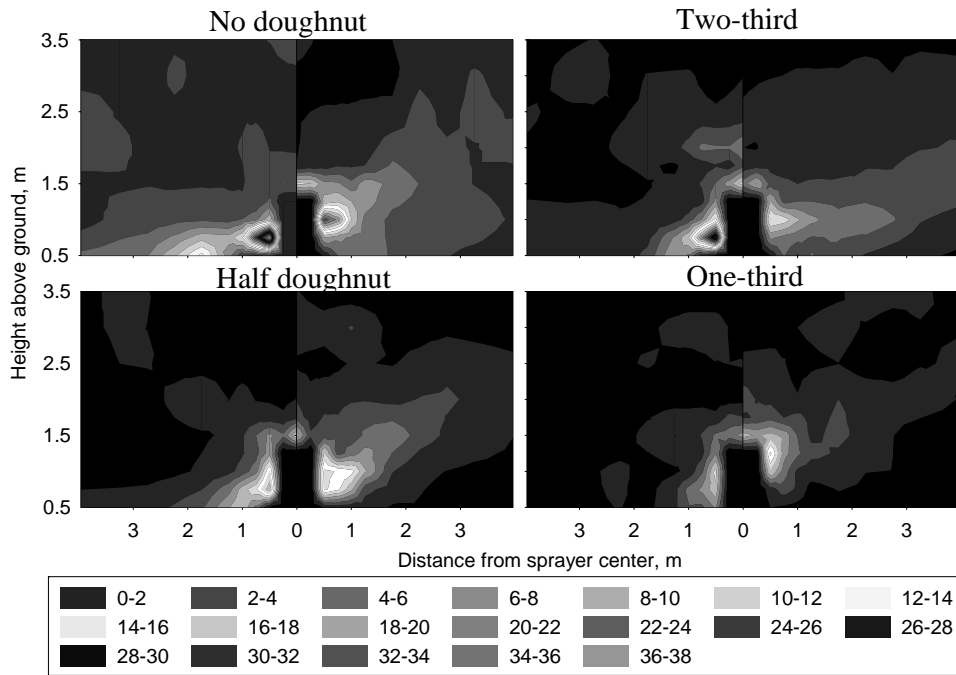


Figure 1: Air-velocity patterns for Berthoud air-blast sprayer with different sizes of air intake

Nozzle type

Increasing the Volume Median Diameter (VMD) will certainly reduce drift, but too large a droplet will bounce off the leaves to the ground, thus causing pollution, wasting money and resulting in less product on the target. Detailed results are published in Landers (2000)

Row from Target	% area covered on cards			
	FARM A Durand-Wayland	Durand-Wayland & air induction	FARM B Kinkelder	Kinkelder & Air induction
1	21.4	7.5	4.3	2.9
2	13.3	3.1	1.9	1.6
3	0.6	2.9	1.1	3.5
4	0.1	1.6	0.1	2.1
5	0.1	1.3	0	0.4
6	0.1	0.6		0.4
7	0	0.3		0.2
8		0		0.3
9				0

Table 2. Drift cards: Farms A and B

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Nozzle orientation

Results from the patternator shows great variability in the spray pattern produced according to nozzle orientation and which side of the sprayer they are fitted. Nozzles set in the “typical growers” pattern, i.e. pointing radially outwards resulted in a large quantity of liquid being blown above the target row. The best spray pattern for the grape zone 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.

Novel sprayers

Results from a series of trials shows the Proptec provided better coverage at 233 l/ha than at 117 l/ha or 467 l/ha. Higher application rates resulted in larger droplets and at the low rate coverage wasn't sufficient to reduce disease levels. Table 2 shows the Proptec reduced drift when compared to the traditional airblast fitted with hollow cone nozzles. When air inclusion nozzles were fitted, the larger droplets came back down and so droplets were recorded up to 3 rows from the target.

The ESS gave very good deposition and coverage at extremely low rates, providing an opportunity for improved logistics and better timeliness. Unfortunately whilst disease and insect control was satisfactory most of the time, there were odd panels within the row which were covered in disease, due to gusts of wind blowing the fine (<50 µm) droplets off-target.

Tunnel sprayers have been well researched by the BBA in Germany and are known to reduce drift by 90%. Our trials we have considered deposition and note that the use of a vertical fan within the tunnel was not necessary in the variety ‘Concord’, a heavy foliage native variety. There was no significant difference between pressure, volume and fan in early – mid season. In full canopy high pressure and high volume of liquid gave significantly better coverage.

The test comparing the air-blast sprayer at 934 l/ha and the CIMA working at either 934 or 467 l/ha showed that, as expected, it was the volume applied that caused differences in deposition rather than the machine type. The CIMA working at 467 l/ha applied less than the CIMA and air-blast working at 934 l/ha (52, 70, and 72.9 % cover respectively). The test comparing bottom and top units showed there was no significant difference between deposits measured for the different unit load, only between canopy depth and leaf side. When only the lower units were used significantly less chemical was deposited to both the top and the centre of the canopy compared to the bottom; with the top receiving less than the centre. Overall the upper leaf surface received more than the lower leaf surface with both application types (57.4 and 25.9%)

Row from Target	%area covered on FORESTVILLE		Cards NAPLES		
	Berthoud	Proptec	Proptec	Berthoud	Berthoud & Air inclusion
1	1.5	0.1	0.7	0.9	3.6
2	0.8	0.0	0.2	0.8	0.5
3	0.5		0.1	0.5	0.1
4	0.3		0	0.2	0
5	0.3			0.1	
6	0.1			0.1	
7	0.0			0	

Table 3. Drift cards: Forestville and Naples

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Results show that novel sprayers which direct spray into the canopy improve deposition throughout the canopy profile, particularly in the middle and centre of the crop, eg. in the fruit zone. Better application in the canopy results in less drift, providing the canopy exists, eg. full canopy provides a good target, whereas early season canopy development still results in drift due to less target.

The Spray Drift Task Force, a consortium of 38 agricultural chemical companies, conducted many tests with airblast sprayers to provide data to support registration of products belonging to their member companies, (Spray Drift Task Force, 1998). Results from spraying 2 metre tall vines in full canopy shows that most of the spray passing the first two rows moved above the top of the vines. Results show that the highest amount measured was less than 0.75% of the total applied active ingredient. The amount of spray moving through the vineyard decreased rapidly and never exceeded 0.06% of the active ingredient at any height after the tenth row. This was due to a combination of droplet settling and the filtering effect of the foliage. The % drift is based upon the amount drifting from the total area to which pesticide is applied, it should be noted that in practice this figure is much higher, particularly in the end rows of a vineyard and particularly when weather conditions such as a moderate wind speed, low humidity and high temperature exists.

Correct adjustment of top and base deflector plates on traditional airblast sprayers should be carried out to direct the air towards, and confine it to the target canopy. Variable pitch blades (if fitted) must be adjusted to vary the amount of air being delivered into the target or alternatively the speed of the fan should be reduced by slowing down the PTO to match the developing canopy.

Conclusions

1. The condition of crop sprayers across the world leaves a lot to be desired, surveys indicate that farmers and growers tend not to maintain them correctly. The design and construction of many crop sprayers is such that it is virtually impossible to empty them completely of pesticide and rinsing them out thoroughly takes a great deal of time.
2. Airblast sprayers, as used in vineyards, create a large plume of pesticide spray due to the use of large capacity fans. The resultant plume of pesticide spray frequently misses the target canopy and is accelerated upwards into the air or through the target canopy.
3. The application of pesticides from an airblast sprayer in a vineyard during high wind speeds, high temperatures and low humidity will result in the product drifting distances ranging from a few feet to many miles.
4. Spray drift is inevitable with crop spraying, even when growers follow best management practices. Research since the mid-1960s indicates that pesticide spray droplets will be transported by wind currents for distances ranging from a few feet to many, many miles.
5. Improved designs of sprayers which direct spray into the canopy, increases deposition and reduces drift, but does not eliminate drift completely.
6. Better application within the canopy results in less drift, providing a canopy exists, e.g. a fully developed grapevine canopy provides a good target, whereas an early season application may still result in drift due to less target area being present to capture the droplets.

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