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Research Focus

Improving Spray Deposition with Engineering Innovation - What a Difference a Decade Makes

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Dr. Andrew Landers' spray technology program provides research and extension to the grape industry to help growers reduce drift and increase deposition.

Photo courtesy Andrew Landers

One of the greatest challenges for grape growers is applying pesticides precisely to the developing target throughout the growing season. As the canopy develops, more air and liquid are required for adequate penetration and coverage.

Our research at Cornell University over the past ten years has focused on developing canopy sprayers that increase deposition throughout the canopy using adjustable air flow and air direction.

Improved deposition may also be attained by correct nozzle selection and orientation, based on testing with a vertical patternator. Trials conducted in vineyards throughout New York and Pennsylvania over the past decade have shown that growers can increase spray deposition by up to 82% and reduce spray drift by 70% by adjusting the airflow coming from the sprayer.

We've developed three novel methods of airflow adjustment with the goal of keeping the air and spray plume within the canopy. The result is that growers have access to new tools and techniques for increasing spray deposition and reducing drift.

Key Concepts

- Airblast sprayers use fans to deliver spray solutions to grapevine canopies.
- Deposition on grapevine foliage is influenced by air volume and speed
- Standard, fixed air volume and speed on conventional airblast sprayers result in increased drift and reduced deposition, particularly early in the season when grapevine canopies are sparse.
- Adjusting air speed to match canopy development can reduce drift by 70% and improve spray deposition by 80%, particularly in early-season sprays.
- Adjusting air direction by re-orienting nozzles improves uniformity of spray deposition and reduces drift.
- Inexpensive spray 'patternators' can be used to show where the spray is going, and adjust nozzle orientation to improve uniformity and reduce drift
- Attention to detail in adjusting airflow and air direction will ensure that expensive sprays are not wasted.

Introduction. Pesticide application methods have been a concern among growers and the general public for many years, not only because of real and perceived problems with off-target drift, but also because any pesticide that is not deposited on its target is not contributing to the purpose of the spray application itself – that is, controlling the target pest or disease. By improving deposition and reducing drift, growers can both avoid wasting costly fungicides and reduce off-target environmental impacts. Accomplishing this requires attention to many inter-related factors affecting spray application, such as the target, the efficacy of the spray, the attitude of the grower, the standard of management, the weather, and many others.

The operation of the canopy sprayer often leaves much to be desired in the vineyard. Most growers know that there are three factors which affect the application rate–forward speed, nozzle size, and system pressure. But progress lies in a better understanding the factors involved in getting the spray from the tank to the target—airflow, liquid flow, forward speed, and canopy structure. Adjusting both airflow and liquid flow to match the growing canopy as the season progresses is the key to increasing deposition and reducing drift.

Airflow is an extremely important part of the application process. The purpose of the air is to carry the droplets from the nozzles to the target while creating a small amount of turbulence within the canopy to aid penetration. Too much air blows the spray through the canopy onto the ground or into the air (drift) and can even dislodge the droplets previously deposited into the canopy when the other side of the row was sprayed. The air assistance in many canopy sprayers comes from large diameter fans which are frequently too large for modern training systems. Ideally air volume should match the canopy volume.

Constant airflow is a not a good match for grape canopies, which can vary along a row; sometimes vines are missing, presenting no resistance to air movement, resulting in air traveling through the target row and away. There are a number of simple methods a grower can adopt to vary the air, such as changing power-take-off (PTO) speed, fitting an air limiting system to the air intake or outlet, or using a variable speed hydraulic motor drive to the fan.

Older sprayer designs, such as airblast sprayers, are prone to off-target spraying. Many growers choose not to replace mechanically reliable yet technologically outdated sprayers. In fact, most growers still use traditional airblast sprayers designed in the 1960s and fitted with drift-prone hollow cone nozzles. Traditional airblast sprayers direct the air from a single axial flow fan in an upward and outward direction. Because axial fans are designed to move large volumes of air at low pressures, spray is emitted from the nozzles into the airstream, sending a large plume of spray into the canopy and often upwards and away, well above the target row.

Two elements of sprayer design hold promise for reducing drift: airflow and liquid flow. The direction, speed, and volume of air should be adjusted to match the growing canopy, especially in early to mid-season, if drift is to be reduced. Droplet size also needs to be considered.

Understanding air flow. In 2001, we were fortunate to obtain the use of an extremely large building at the old Seneca Army depot at Ovid, New York, to conduct indoor airflow trials with an airblast sprayer. The large building (280′ x 54′ x 60′) eliminated experimental errors caused by ambient wind and interference from the walls and roof. We monitored air speed and direction using simple frames fitted with monofilament line and cotton ribbons and helium-filled soap bubbles with neutral buoyancy.

To direct the air to the crop canopy, we devised a set of deflectors which reduced airflow above the canopy height. In subsequent field trials, we found an improvement in deposition of 30%, with much better deposition throughout all regions of the vine canopy. However, the trials showed us we had a large volume of air blowing great distances through and past the target canopy. We decided we needed to limit the airflow, either at the air inlet or outlet or by changing the fan speed.

To do so, we developed the Cornell "doughnut"—a circular air restrictor mounted on the air intake of the sprayer (**Figure 1**). A series of three "doughnuts" were designed, with the circular hole in the middle varying in size, allowing the operator to match airflow with the growth stage of the canopy.

***Figure 1:** Cornell "doughnut" used to restrict airflow from airblast sprayer fan.*

Photo courtesy Andrew Landers

The result was reduced drift and increased deposition.

Adjusting airflow. One of the simplest ways of reducing drift is to shut down the fan speed by lowering the tractor engine speed and subsequently lowering the power-take-off (PTO) speed. In field trials we found that by lowering PTO speed by 25% we could reduce drift by over 75%. This dramatic reduction in drift was accompanied by reduced fuel use and noise.

In trials with canopy sprayers at the Field Research Unit at NYSAES (Geneva, New York), we showed that adjusting airspeed can improve deposition considerably. We conducted field trials using an AgTec sprayer (similar to the ubiquitous Kinkelder sprayer) fitted with airshear nozzles operating at two fan speeds: 2076 rpm (540 rpm PTO) and a 25% reduced speed of 1557 rpm (405 rpm PTO). To detect drift, we used water sensitive cards which were analyzed using image analysis software.

At the higher fan speed of 2076 rpm, we detected drift (10% card coverage) up to 80 feet from the target row. Reducing fan speed by 25% with a slower PTO speed resulted in considerably less drift, with card coverage at 80 feet dramatically reduced to 0.20%. A number of manufacturers now offer adjustable airflow. For example, some adjust the airflow by changing fan blade pitch or altering hydraulic or electric flow to multi-head fan sprayers.

Air speed and volume can also be altered by changing the sprayer fan speed using a hydraulic motor and oil flow controller to adjust input speed to the fan, providing infinitely variable speeds from 0 to 540 rpm. An infinitely variable fan speed allows the grower to adjust the air speed near sensitive areas and match airflow to canopy development. Many grape growers have mechanical harvesters awash with hydraulic motors that are idle all summer and can be used for this purpose.

We have also recently developed an adjustable air outlet for both traditional axial fan airblast and tower sprayers (**Figure 2**).

***Figure 2: Top:** Adjustable louvre. An electronic actuator moves the louvre forward or backward to reduce or increase airflow. **Bottom:** Adjustable louvre fully open (left) and closed (right)*

Photo courtesy Andrew Landers

Spray louvre experiment. In 2009 we fitted an FMC tower sprayer with adjustable louvres for trials at the NYSAES. We were able to reduce drift by 71% and improve deposition by 82% in early season application (Table 1). As the season progressed, the larger, more dense canopy intercepted more of the spray droplets. We found that in late season we needed maximum airflow to give the best deposition.

Grower trials. In 2010, two FMC Economist® air blast sprayers belonging to two growers in the Finger Lakes region were fitted with electric actuators which move an adjustable louvre fitted to each side of the sprayer. The louvres allow the operator to change air volume to match the changing canopy to reduce drift. Where the air blows the droplets will surely follow. Therefore, if drift is reduced, deposition within the canopy must be improved.

Table 1. Change in drift and spray deposition in response to open or adjusted louvres restricting airflow in a Vignoles vineyard at the NYSAES in 2009.

Louvres Position	Early Season Open	Early Season Adj.	Mid Season Open	Mid Season Adj.	Late Season Open	Late Season Adj.
Drift reduction (%)	-	**71***	-	**37***	-	**18**
Deposition increase (%)	-	**82†**	-	**55**	**14**	-

* Dye concentrations on pipe cleaners were significantly lower when louvres were adjusted.
† Dye concentrations on leaves were significantly higher when louvres were adjusted.
Adj. = louvres adjusted Open = louvres fully open

We also conducted deposition trials in a vineyard block of the grape cultivar GR7 near Ovid, New York (Table 2), and observed a 20% improvement in deposition when the airflow was reduced compared to when the louvre was fully open. These results show the benefit of airflow adjustment in early to mid season.

Table 2. Tracer deposition on GR7 leaves, May 20, 2010*

Location on vine	Louvre position: Fully open — Deposition ug/cm^2	Louvre position: Adjusted — Deposition ug/cm^2
Left top	2.21	2.55
Left bottom	2.98	3.73
Average	2.60	3.14
Right top	2.23	2.09
Right bottom	2.20	3.17
Average	2.22	2.63

*Berthoud Sprayer @ 35 GPA, three replicates, applied to GR7 vines at Ovid, New York

In the Vignoles canopy at NYSAES, we also measured drift reduction by adding a fluorescent tracer to the sprayer and using pipe cleaners attached to 14' tall poles to capture the fine drifting droplets. With the adjustable louvre open (**Figure 3, top**) there was significant drift from ground level up to 13 ft above the ground. With the louvre adjusted to reduce air flow (**Figure 3, bottom**) we were able to substantially reduce drift.

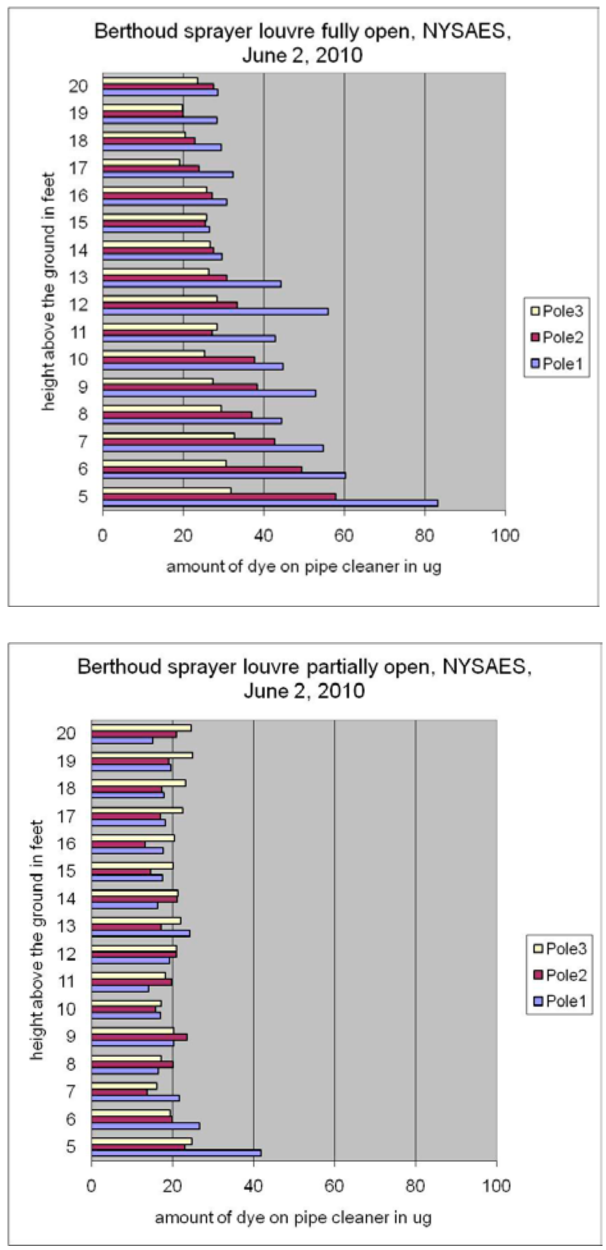

Figure 3: *Spray drift with louvres fully open (top) or adjusted to limit airflow (bottom).*

Liquid flow. Traditionally, hollow cone nozzles have been used for spraying fruit crops. The fine droplets provide excellent coverage but, unfortunately, sometimes add to the drift problem. Air induction nozzles, which produce less drift-prone droplets that are larger and hollow, have proven to be well suited to herbicide spraying in vineyards, and I commend them to all growers. We conducted field trials from 2005 to 2008 to determine if air induction nozzles in a canopy sprayer could be effective. Results proved extremely positive at controlling drift and indicated no significant difference in controlling vine canopy diseases.

Patternator. A vertical patternator can be used to demonstrate the direction of the spray cloud as it leaves the sprayer. The patternator comprises a series of stainless steel plates attached to a mast which passes through the spray plume. Liquid collects in the plates and runs down into collection vessels.

The patternator demonstrates two major issues with axial fan sprayers: the non-symmetry between the left and right sides of the sprayer and the amount of spray overshooting the target canopy. We can alter nozzle orientation and get near perfect adjustment so that the spray cloud hits only the target canopy and directs the same spray pattern from each side of the sprayer; all at a zero cost adjustment for the grower.

We purchased a vertical, stainless steel patternator to use as a repeatable standard in our research trials when we modify canopy sprayers ***(Figure 4)***. We have also used it to test over 80 sprayers during extension meetings. Unfortunately this patternator is an expensive research tool, so we designed an inexpensive ($400) patternator for growers based on window screens.

When it rains, you might notice that water runs down the fly screen next to your window, yet the glass remains dry! We use window screens with small collection gutters attached; liquid runs from the gutters to collecting jars and enables the growers to adjust their sprayer nozzles accordingly. A growing number of grape growers have built patternators based upon the Cornell design.

Conclusions. Attention to detail allows the operator to make adjustments to the sprayer. Changing airflow direction and volume not only improves deposition but also reduces drift. Novel techniques such as adjustable louvres allow air adjustment on the move to match air flow to the changing canopy. Louvres reduce drift and improve deposition par-

Figure 4: *Research patternator with 'air shear' Kinkelder sprayer.*

Photo by Andrew Landers

Figure 5: *Collection tubes illustrate spray distribution.*

Photo by Andrew Landers

Figure 6: Inexpensive patternator built out of window screens. Plans are available at:

http://www.nysaes.cornell.edu/ent/faculty/landers/pestapp/PATTERNATOR.htm ticularly during early to mid season when minimum foliage exists to intercept the spray.

The narrower, well manicured *vinifera* canopy, provided by Vertical Shoot Positioning canopy training, requires a totally different air speed and air volume when compared to single curtain or Geneva Double Curtain-trained *labrusca* vines with a drooping growth habit. Air speed should change between blocks of different growth stages and varieties/trellis designs—one size doesn't fit all! As with all farm operations, spraying requires thorough preparation, attention to detail, and constant vigilance if mistakes are to be avoided and an efficient application is to be made.

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Further reading:

Landers, A.J. (2010). Developments towards an automatic precision sprayer for fruit crop canopies. Presented at the 2010 ASABE Annual International Meeting, Pittsburgh PA, Paper No. 1008973, ASABE, 2950 Niles Road, St Joseph, MI 49085-9659

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Landers, A. J. (2007). Pesticide Application Technology web page. http://www.nysaes.cornell.edu/ent/faculty/landers/pestapp/

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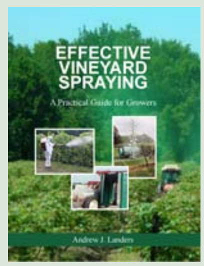
Effective Vineyard Spraying
A Practical Guide



Andrew Landers has written a 260 page book on vineyard spray technology aimed at growers and industry. It includes a CD with video demonstrations of various topics. For more information:
www.effectivespraying.com

Using Simple Technology To Improve Spray Deposition and Reduce Drift at Dalrymple Vineyards

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I first saw Andrew Landers demonstrate his spray patternator at a field day demonstration in 2004. It inspired me to build my own. The unit I built cost me less than $50, and as you can see is made mostly out of old window screens I had laying around. Each screen has a channel in the bottom that funnels the water into the seven gallon-sized jugs, so I can run my sprayer for 15 minutes and find out how evenly the water is being distributed in the canopy.

When I first tried it out with my standard sprayer settings, it was throwing spray way up to the top, which obviously wasn't making it into the vine canopy. I was able to change the direction that nozzles were pointing to adjust for the direction of air coming out of the fan - downward on the left side to counteract the upward air movement (the fan turns clockwise), and slightly upward on the right side to counteract the downward air movement. I also ended up changing nozzle size in some of the positions where overlap in coverage by two nozzles resulted in uneven volume. By making these adjustments, I was able to get uniform coverage and target the deposition on to the canopy, instead of having half of it shoot into the air. It greatly reduced drift.

I worked with Andrew and Emilio Gil on using the "Dosavina" program on my farm. It uses vine dimensions, growth stage, spray material, variety, and spray conditions to calculate an optimum amount of water to deliver per acre. Early in the season, I was able to mix my fungicides in the appropriate concentration for 50 GPA, but actually apply much lower volume - down to as low as 17 GPA in some cases. I feel we got the same coverage while applying much less material per acre. We didn't need so much water to cover the relatively small leaf area present before bloom, and we figure we've saved around $2000 - $3000 on spray materials annually on our farm.

The sprayer adjustments I made with my homemade 'patternator' allowed me to be confident that I was getting good coverage, and not losing a lot of material to spray drift or spraying it on to the ground. Overall, this has helped us be more environmentally conscious, while also saving us money. It's been a big benefit all around.

Spray patternator made of old screen windows. Airblast sprays into screens (left) and spray water drains through channel at bottom of screen (center) to individual bottles (right). The amount of water draining to each bottle is then measured.