IMPROVED PESTICIDE APPLICATION TECHNOLOGIES

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The application of pesticides has been of concern for many years, particularly methods of reducing drift and improving deposition. There are many inter-related factors which affect spray application depending upon the target, the efficacy of the spray, the attitude of the operator, the standard of management, the weather etc.

The operation of the sprayer often leaves much to be desired. Most growers know that there are three factors which affect application rate: forward speed, nozzle size and system pressure but often overlook the factors which help get the spray onto the target: airflow, liquid flow, forward speed and canopy structure. Progress lies in a better understanding of the factors involved in getting the spray from the tank to the vines. Adjusting both airflow and liquid flow to match the growing canopy as the season progresses is the key.

Airflow

Airflow is an extremely important part of the application process and excessive air speed and volume is responsible for spray drift. The purpose of the air is to carry the droplets from the nozzles to the target as well as create 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) or dislodges the droplets previously deposited into the canopy when the other side of the row was sprayed. Many vineyard sprayers use some form of air assistance from fans which are frequently too large for modern, well-pruned training systems; the large diameter fan creates too much air for the target canopy. The ideal air volume should match the canopy volume. Canopies vary along the row; sometimes vines are missing, presenting no resistance to air movement, resulting in air traveling through the target row and away. Air speed and volume need to be adjustable according to the growth stage of the canopy. There are a number of simple methods a grower can adopt to do this, such as changing PTO speed, fitting an air limiting system to the air intake or outlet or using a variable speed hydraulic motor drive to the fan.

Trials with various types of vineyard sprayers have been conducted at Cornell University to study how changes in fan speed affect air speed, volume and direction. For some years I have shown growers that reducing airflow via a reduced air intake design will improve deposition in the canopy and reduce drift. A simple device, christened the "Cornell doughnut", is made of plywood or metal, see Figure 1. It is the same size as the fan intake with a hole $^{1}/_{3}$rd, ½ or $^{2}/_{3}$rds of the air intake cut in the centre. The doughnut reduces air intake and you select the larger sized holes as the canopy develops.

Figure 1. Cornell doughnut on air inlet   Figure 2. Adjustable louvre on the air outlet

We have also recently developed an adjustable air outlet for both airblast and tower sprayers, Figure 2. An electric actuator moves an adjustable louvre allowing the operator to change air volume to match the changing canopy and reduce drift by as much as 71% in vineyards in early season application. Where the air blows the droplets will surely follow. Therefore, if drift is reduced, deposition within the canopy must be improved. Modifying air flow at the air intake or outlet has resulted in up to 30% improvement in canopy deposition.

Traditional airblast sprayers using a fan rotating in a counter-clockwise direction, move air downwards on the left-hand side of the sprayer and vice-versa on the right-hand side. The result is often a large plume of spray going upwards and outwards on the right hand-side of the sprayer and uneven application within the canopy. This also does nothing to help public perception of the application of pesticides to fruit crops!

Airblast sprayers fitted with towers, adjustable air outlets or multi-head fans provide better airflow characteristics, and therefore better deposition into the canopy than do traditional designs. In trials we have shown up to 30% better deposition throughout the canopy by using tower sprayers. Adjustment of top and base deflector plates on traditional airblast sprayers should also be carried out to direct the air towards, and confine it to, the target canopy.

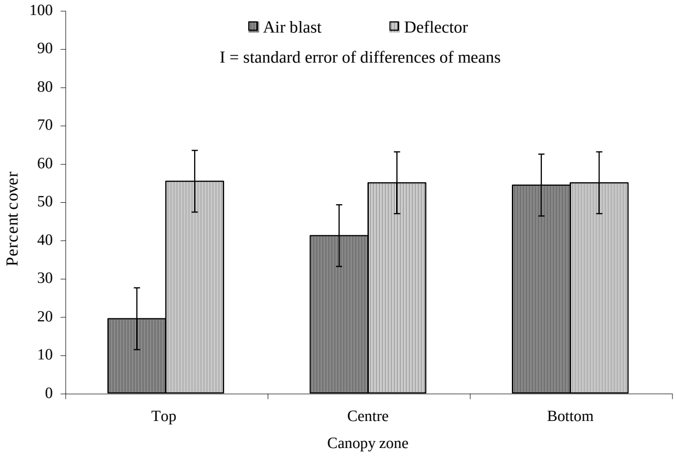

Figure 3. Improved deposition throughout the canopy using a deflector or tower

Adjusting the airspeed can improve deposition considerably. Field trials were conducted using a sprayer fitted with airshear nozzles operating at two fan speeds, 2076 rpm (540 rpm PTO) and at a 25% reduced speed of 1557 rpm (405 rpm PTO). Drift was detected using water sensitive cards and then analyzed using image analysis software. At the higher fan speed of 2076 rpm, drift was detected up to 80 feet from the target row where 10% card coverage occurred. Reducing fan speed by 25% with a slower PTO speed resulted in considerably less drift, with card coverage at 24m being 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 electricity flow to multi-head fan sprayers.

Liquid flow and canopy structure

There are two main aspects to consider when applying liquids, the volume of product and the volume of water. Many growers typically apply X gallons per acre pre-bloom and then Y gallons per acre post-bloom with the intention of getting good leaf coverage. Unfortunately poor spray coverage is a major factor contributing to poor insect and disease control. Better coverage leads to better control and a thorough application of an effective material is required. Uneven coverage increases the amount of pesticides that must be applied in order to provide adequate control on poorly covered areas and can increase the number of sprays required if it allows insects or a disease to become established. Applying the correct amount of spray at the correct time to the correct target is good advice.

Canopy size and shape will affect application volume and there are as many dangers in not applying enough spray as there are in applying too much. There is an optimum quantity required for a thorough coverage of the target. The old adage that you should spray until the leaves drip is misplaced; likewise lowering spray rates to below the minimum which offers control is also misguided advice. Increasing spray application volumes leads to higher losses to the ground and lower deposition on foliage.

The tunnel or recycling sprayer provides the ultimate in both drift control and canopy sensing. As only the vine and foliage intercepts the spray it requires, excess is returned to the tank providing savings of up to 75% in spray use in early season and average of 30% over the whole season.

What is the optimum volume to apply per acre? The aim of good pesticide application is to provide many small/medium droplets which will stick to the surface of the leaf and, as every canopy is different, due to growth stage, variety, trellis climate etc., the only way to know is to look at the canopy. Avoid over-application from applying too much liquid or driving too slowly. Avoid under-application by driving too fast, using too little volume or too much air.

Growers can use a variety of safe methods using clean water and:

- Water sensitive cards and strips**,** attached to the leaves with paper clips or staples as long as the canopy is dry and the user wears rubber gloves. They are quite expensive but show where water droplets have hit the upper or lower leaf surfaces and how close the water deposits are to the grape cluster.

- High quality photographic paper cut into 2” x 1” strips attached to the leaves and used in conjunction with a readily available kitchen food dye. Quality photo paper can be purchased at office supply shops for printing digital photos. Alternatives include plain glossy business cards or file cards.

- Surround as a tracer**.** Surround, an organic insecticide, based upon Kaolin clay, is highly visible on most green vine leaves and grapes. It should be premixed in a bucket before putting into the spray tank, otherwise it will block the filters. Keep tank contents agitated. The spray will dry rapidly on a summer day and in approximately 10 minutes you will see all the droplets over the leaves and grapes.

- Fluorescent tracers and an ultra violet **(**black-light) lamp provide an excellent means of seeing where the droplets have landed, Figures 4 and 5. Figure 5 shows excessive application leading to run-off, resulting in less product being retained on the leaf. Growers have to wait until dark to see the droplets in the canopy or remove leaves to view in a darkened area. Inexpensive black lights are available on the internet.

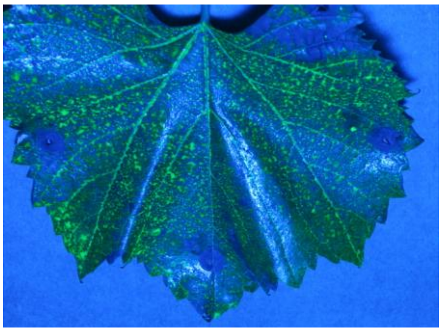

Figure 4 Coverage: 35gpa at 3mph

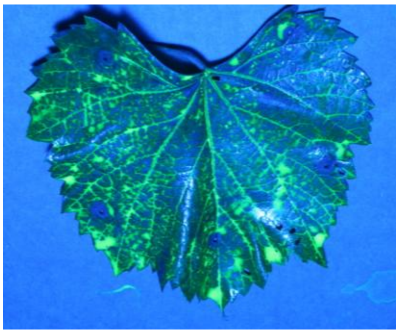

Figure 5 Coverage: 75gpa at 3 mph

Nozzles

When applying pesticides, growers know that small or fine/medium droplets give the best coverage, as large droplets (in excess of 300 µm) will bounce off the leaves onto the ground. Good coverage is critical for all contact pesticides. Unfortunately small or fine droplets (less than 150 microns) are drift-prone if they don't become attached to the target leaf, insect or clusters. Directed deposition is needed if pesticide is to be applied to the target zone. 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. Air induction nozzles can be used in the canopy sprayer to reduce drift considerably. They can reduce drift from occurring as far as seven rows away down to one or two rows and are ideal when spraying next to sensitive areas.

The orientation of the nozzles can also be adjusted on many sprayers to reduce drift. For example, 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 quantity overshooting the target varies according to canopy height, density and size/speed of the fan. There is a great in-balance of distribution between the left and the right-hand side of the sprayer due to the airflow characteristics and nozzle orientation. When nozzle orientation is adjusted for differences in fan rotation, there can be a 20% improvement in spray deposition in grapevines.

To assist in adjusting the nozzles, a vertical patternator can be used. The Cornell University patternator comprises nine 14" x 48" wide fly screens connected via hooks to two 14' high, 4" x 2" wooden boards. A small gutter is attached, at an angle, to the bottom edge of each screen. The gutter slopes to one end where a plastic hose connects it to a box containing graduated measuring cylinders. The sprayer tank is filled with clean water, the patternator is placed at the end of a row and the sprayer is operated but remains stationary As the spray cloud hits the fly screen, air passes through and liquid runs down the front of the screen, into the gutter and then, via the plastic hose,

into the collecting cylinders. Plans for the construction of the Cornell patternator are available on the internet at:
http://www.nysaes.cornell.edu/ent/faculty/landers/pestapp/PATTERNATOR.htm

The results show the importance of correct nozzle orientation if pesticides are to be applied effectively onto the target. It should be noted that each sprayer design will vary, due to fan size and air volume, so no "blanket' recommendation can be made.

The patternator is a very useful tool in both research and extension. In research it allows us to make changes to the sprayer and see repeatable results compared to the original settings. In extension it demonstrates to growers the quantity of spray plume going up and over the canopy – it shows the symmetry, or lack of, between left and right side of the sprayer, and it teaches the importance of adjusting the sprayer correctly to improve deposition and reduce drift. Over 75 sprayers have been evaluated in the past six years, in both orchards and vineyards. One apple grower, for example, has adjusted nozzle orientation and reduced his pesticide use by 20% while maintaining the same coverage. Other growers choose to apply the full 100% of spray into the target area.

The operator

Correct filling routine, personal protective clothing and calibration should be standard practices. Calibration of vineyard sprayers can be seen on the internet at You Tube, showing both measuring liquid flow and also nozzle selection. Sprayer operators need to remain alert, checking changing weather conditions and the use of a hand-held anemometer is recommended. Much remains to be done, one-day operator training classes provide in-depth instruction on sprayer operation, a subject often neglected.

Forward speed

The sprayer should be operated at a speed consistent with spray penetration into the canopy. Driving too slowly in a sparse, early-season canopy will result in spray blowing through the row; conversely, driving too fast in a full canopy results in poor penetration. Watching what is happening, along with checking on deposition as mentioned earlier, will result in the optimum speed.

Automatic spraying

The ultimate variable rate, fully automatic canopy sprayer may comprise many of the aspects described in this paper. The sprayer travels along the vine rows, monitoring either presence or absence of the canopy plus canopy size and volume. Ultrasonic or infra-red sensors monitor the dimensions of the canopy and thus alter both airflow output from the fan and liquid flow (application rate/acre) according to the variable canopy.

Patches of diseases or insect activity may have been located previously by scouting the crop, their exact location recorded on a hand-held GPS device. Research has shown how the application rate of pesticides varies considerably with canopy volume and growth stage. In Riesling and Cabernet Franc varieties on a VSP trellis, for example, we found the application rate requirement of the canopy varies from 16 gpa in early season to 50 gpa in full canopy. To monitor the variation in the canopy we have recently developed infrared sensors mounted on the sprayer to detect the absence/presence/height of the canopy and in turn switch on/off nozzles corresponding to the canopy height. Infrared sensors provided a reduction in pesticide use of up to 40% in the first three sprays of the season, Table 1.

Infra-red sensor trial 2009	Reduction in spray use
Early season 3rd June	40%
Mid-season 17th June	18%
Full canopy 6th July	0.3%

Table 1. Reduced spray use with Infra-red sensors Vignoles trial, NYSAES

Education

The answer to improved pesticide application in the vineyard is within the ring-fence of the skull. Growers and operators should read, read and read. The latest information on effective vineyard spraying maybe found in a new book entitled Effective vineyard spraying by the author. The book covers all aspects of vineyard spraying and uses the theme of accurate application through practical innovation. For further details see www.EffectiveSpraying.com.

Conclusions

Attention to detail allows the operator to make adjustments to the sprayer. Changing airflow direction and volume not only improves deposition but reduces drift. Novel techniques such as adjustable louvres allow air adjustment on the move and matches air flow to the changing canopy. Measuring canopy volume and adjusting spray volume accordingly reduces spray use when applied with a correctly adjusted sprayer. Using cards or tracers will inform the operator of good coverage, canopy penetration and drift. Sensors can also be used to adjust liquid flow to match the canopy and reduces spray use particularly in early season when minimum foliage exists to intercept the spray. Air induction nozzles reduce drift. 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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Dr Andrew Landers *studied and taught agricultural engineering in England. He obtained his masters degree at Silsoe College, Cranfield University and his Ph.D at the University of Bath. He taught agricultural students at the Royal Agricultural College before becoming head of the engineering dept at Harper Adams University. He joined the faculty at Cornell University in 1998, and is based at the New York State Agricultural Experiment Station in Geneva. He directs the application technology program and his teaching/extension/research appointment involves the use of engineering solutions to provide safer spraying. His group works with application systems in grapes, apples, vegetables and turfgrass and he believes in a multi-disciplinary approach to pesticide application, working with biologists to ensure engineering techniques are biologically effective.*

In 2007 he was presented with the College of Agriculture & Life Sciences at Cornell University award for outstanding accomplishments in extension and outreach. In 2010 the New York Wine and Grape foundation presented him with the Research award for major contributions in research and education.

Andrew Landers is author of Effective Vineyard Spraying, published by www.Effectivespraying.com