FINAL REPORT

Washington State Grape and Wine Research Program

DUE June 30, 2019
by email to: ARCGrants@wsu.edu

PROJECT TITLE: Assessment of Application Technologies in Wine Grapes

Project Duration: ***(List Years) 2015-2017+1yr extension***
WRAC Project No.: 13B-4127-1523

PI Name:	**GWEN-ALYN HOHEISEL**
Organization	WSU
Address	1121 DUDLEY AVE PROSSER, WA 99350
Telephone	509-788-5459
Email	ghoheisel@wsu.edu

CO-PI Name:	**MICHELLE MOYER**	**CO-PI Name:**	**LAV KHOT**
Organization	WSU	Organization	WSU
Address	24106 North Bunn Rd Prosser, WA 99350	Address	24106 North Bunn Rd Prosser, WA 99350
Telephone	509-786-9234	Telephone	509-786-9302
Email	michelle.moyer@wsu.edu	Email	lav.khot@wsu.edu

Cooperator Name:	**BILL RILEY**	**Cooperator Name:**	
Organization	Ste Michelle Wine Estates	Organization	
Description of participation:	Coordination of field trials on 90-100 acres at SMWE, plus the use of a directed sprayer with standard hollow cone nozzles	Description of participation:	

FINAL REPORT

BUDGET AND OTHER FUNDING SOURCES

FINAL FINANCIAL REPORTING

BUDGET *(LIST COMPLETED BUDGET NUMBERS)*

	Year 1 FY	**Year 2 FY**	**Year 3 FY**
	Jul 15 – Jun 16	Jul 16 – Jun 17	Jul 17 – Jun 18
Total	$32,000	$53,615	$50,000

Footnotes:

Also included a 1-year, no cost extension from Jul 18 – Jun 19.

This project would not have been possible without manufacturers and grower cooperation by loaning tractors, sprayers, and technician time. A summary of other funding sources:

Agency Name: Washington State University Viticulture and Enology Program
Amt. awarded: $29,224 for one, 12-month PhD Assistantship, stipend and benefits
Agency Name: WSU and other grant agencies
Amt awarded: $6000, cost share for a fluorometer
Agency Name: VineTech Equipment
Amt. awarded: $3,000 for 2 years in the form of a technical support and parts
Agency Name: Blueline Manufacturing
Amt. awarded: $11,000 for 2 years in the form of a donated Gregoire sprayer
Agency Name: On Target Spray Systems
Amt. awarded: $2,000 of one year in the form of technical support
Agency Name: St. Michelle Wine Estates
Amt. awarded: $24,500 for 2 years in the form of 3 loaned tractors and sprayer
Agency Name: Four Feathers
Amt. awarded: $14,500 in one year in the form of a loaned tractor and sprayer

Total Project Funding: $135,615 (cost share $128,724)

Project Budget Status: *Year 1 had funding start in the middle of the summer, so we did not start field trials until Year 2. Deviation from objectives were only related to eliminating one machine from being tested because manufacturer withdrew from market. Alternatively, by request of the committee, we tested several new technologies and nozzles on airblast sprayers.* ***Funding of this project, showing support from the industry, led to the funding of several other grants and projects.*** *More specifically, a second PhD student, Haitham Bahlol, who was in Dr Khot's lab and funded by other sources, was able to develop and field test a Smart Patternator to assess vertical spray and air patterns. This technology is being patented and will be used to quickly assess other technologies in a rapid fashion. Additionally, because our lab and team had the expertise and equipment to evaluate deposition the Washington Tree Fruit Research Commission (WTFRC) funded the first of 4 trials to collect data for a new model to be used by EPA for assessing risk when making labels and laws. The Washington grape industry, our lab, WTFRC, and UC Davis are collaborating to determine the best path to collect data in grapes. Lastly, PhD student Margaret McCoy secured an NSF Fellowship grant to continue to evaluate application technologies for the next two years. This supports her salary and research and would not have been possible without demonstrating support from the industry.*

FINAL REPORT

Project Summary:

Improper spraying can lead to significant economic losses and negative environmental impacts from off-target drift. The axial fan rotation on conventional airblast sprayers produces non-symmetrical spray deposition and due to the high velocity of air, spray can travel through the canopies missing the target. There are methods to optimize airblast sprayers to increase coverage in vineyards, but other sprayer designs also show promise. Adoption of these newer technologies has been slow and none of these sprayers have been evaluated in Washington vineyards.

This study evaluates novel, commercially available sprayers and nozzle technologies. Large plots are sprayed through the season with a single sprayer. We measure canopy deposition, in-field drift (aerial and ground), mildew control, operating efficiency. There are also small plot field studies assessing optimization of axial fan sprayers testing the number of nozzles open and three different nozzles (disc-core, one-piece, and air-induction). Lastly, Extension and outreach objectives include dissemination of information through written material, grower meetings, and the development of a short course for viticulturist and a one-day sprayer technology class.

Evaluation of spray equipment will provide information to develop best management practices (BMPs) for alternative spray technologies which should help growers operate technologies appropriate for the needs of various systems and farm operations. We hope this project establishes a foundation for learning and changing application practices. In addition, it should serve as a model of how projects can train the next generation of Extension faculty. It is applied research, translated to education, and funded partially by cooperating partners and WSU Extension.

Project Major Accomplishments: *(No page limit)*

Accomplishments for specific objectives funded are listed below, but a major accomplishment from the team is the significant number of other projects leveraged from this project.

- Partial funding of a fluorometer (also funded by blueberry and tree fruit industries) equipped our lab for deposition studies. This includes: 1) evaluation of drones used for spraying in vineyards, 2) data for a mechanistic model used by EPA https://youtu.be/wwAmAj-OrDI, 3) WSDA and NIFA-FFAR grants for development of novel spray technologies.
- Margaret McCoy, PhD student on this project, has been awarded a NIFA Fellowship that funds her salary and research for the next two years. She needed to show industry support and did so with this grant. She will be studying electrostatic sprayers in more depth and creating Extension curriculum for the grape industry.
- A second PhD student, Haitham Bahlol, who is in Dr Khot's lab was funded through other sources but was able to conduct additional research to help this project. Haitham has built and tested a smart analytical spray system (SASS) that was tested with sprayers from this project. The SASS measures air and vertical spray patterns. It is being used in the EPA grant (mentioned above) to assess different sprayers.
- Data from this project was used to inform legislatures and participants of the Senate Bill 6529 (2018) establishing a Pesticide Application Safety chaired jointly by Senator Rebecca Saldaña and Representative Tom Dent. Hoheisel's participation included touring

the state with committee and presentations on technologies used that minimize drift. A final report of SB6529 was created by DOH. https://www.doh.wa.gov/DataandStatisticalReports/EnvironmentalHealth/Pesticides/ApplicationSafetyWorkgroup

Objective 1: Application Technology Research.

There is a considerable body of knowledge about new application technologies, but research describing and comparing spray technologies and optimizing them for crop- and canopy-architecture-specific applications assessing coverage and control over large acreage is scarce. The research goal of this proposal is to obtain detailed knowledge to compare important spray equipment parameters to help growers be more efficient in targeting pests.

For Quantum Mist, Gregoire, and On Target sprayers, studies were season long over large acreage of land and parameters include: 1) canopy deposition; 2) in-field drift; 3) disease control; and 4) sprayer efficiency/best management practices. For airblast sprayers, deposition was compared for different nozzles open and types of nozzles on the market. A summary of the results is given here as a detailed manuscript and additional data analysis is in preparation for both peer reviewed journal paper and Extension Fact Sheet.

Field deposition measurements of three sprayers occurred at various times over two years (2016-2017) in early and full canopy. Season-long efficacy trials and single-event deposition trials were conducted at SMWE (Gregoire and Quantum Mist) and Four Feathers (On Target) following ISO standards (ISO 22522:2007E) (Fig. 1). Individual plots were 20-30 acres and replicated in the vineyard. Specific parameters for each sprayer are in Table 1. Spray deposition, the amount of material on 2x2in cards, was assessed with Pyranine, a food-grade coloring agent. Five cards per zone (3 along the top canopy and 2 on each side of the fruiting zone) were collected at SMWE, but because of the strict VSP at Four Feathers, 4 zones were established by eliminating the upper middle zone (Fig. 2). Treatments were applied on each side of a row. Cards were processed for fluorescence on 10-AU Fluorometer in the lab. The absorbance in ppb was converted to ng/cm^2 and normalized for differences in rates (GPA) across the season. This allows us to compare early and late deposition regardless of the sprayer set-up.

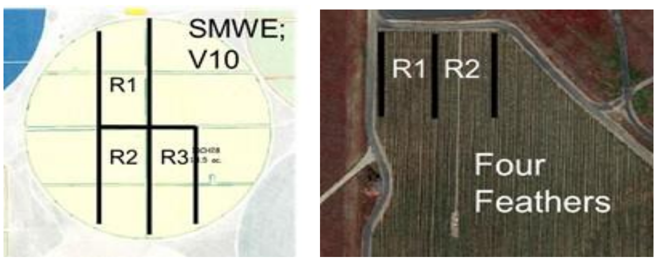


Figure 2: Large plots in cooperating grower fields were a single sprayer was used in that area over the entire season


Figure 1: Plastic collection cards in 5 zones per vine and replicated 5 times.

Table 1: Sprayer configuration for season-long studies

Sprayer	GPA		Nozzles		
	Early	Late	Early	Late	
Quantum Mist	50	75	4 VisiFlo Tx-Vk4 per fan, 2 fans per half-row	6 Visiflow Tx-Vk4 per fan	
Gregoire	25	50	3 pneumatic nozzles per white ‘sock’, 1 sock per half-row	5 pneumatic nozzles per white ‘sock’, 1 sock per half-row	
On Target	20	20	5 pneumatic nozzles per white ‘tube’, 2 tubes per half-row	5 pneumatic nozzles per white ‘tube’, 2 tubes per half-row	

<u>Overall:</u> For all sprayers, there were specific techniques and maintenance requirements that needed to be updated before the trials. Specifics for each sprayer will be listed below, but it is our experience from these trials and private calibrations that maintenance, proper nozzle alignment, and cleaning are vastly over-looked in these machines. This will have an affect on the deposition and quality of spray. Before all our trials, sprayers were calibrated and underwent routine maintenance.

We examined deposition in the canopy of the spray row and drift on the ground and air 1, 2, and 3 rows beyond the spray row. For all sprayers we are representing the percentage of material caught from the last season’s trial and will note when there are discrepancies with previous years. In addition, **percent deposition represents the proportion of the total that we collected, not the total mass from a sprayer.** Total mass balance studies that capture all material from a sprayer were beyond the scope of this study. *As with all spray studies, looking at absolute numbers is less helpful than looking at trends. Deposition will be influenced by environmental factors and differences in sprayer operation*

For all sprayers across all years, deposition was high in the spray row accounting for 80-98% of all material we measured. There was always more drift in the first row from the sprayer, but overall low drift on all these new spray technologies. In fact, there was 6-8 times less ground deposition and 300-400 times less aerial deposition when compared to the canopy deposition collected. Showing that when these sprayers are maintained well and optimized for the canopy, they perform very well with minimal drift.

<u>*Quantum Mist:*</u> These sprayers are manufactured by VineTech and feature a Sardi fan. They can come in many configurations and placements of fans, but ‘over-the-row’ is the most common for vineyards. The sprayer we used was a 3-row machine with 12 fan heads (Fig. 3) that should be aimed at the canopy and about 24-inches away. Fans can move during applications, so we recommend checking the alignment at each tank fill. Each fan has a minimum of 6 nozzle bodies, which can have a blank disc if not in use (Fig. 4) but the Visiflow used emitted a ‘very fine’ drops (61-105 um). However, unlike the other sprayers, these nozzles are exchangeable, potentially varying droplet size. In the early season, if only 4 nozzles are used, place them opposite of each other. For example, nozzles could be in position 1, 2, 4, and 5. They should not be placed in a row in positions 3-6 as this will affect the spray pattern leading to a more streaks (i.e. areas of higher deposition). Annual inspection should include replacement of broken/chipped fans, cages, and worn nozzles. In addition, this sprayer has a rate controller that verifies speed with a gps. The gps must be mounted to the sky and have speed checked manually once per year (for methods go to: http://treefruit.wsu.edu/web-article/six-steps-to-calibrate-and-optimize-airblast-sprayers/). If the rate controller does not match manual verification, then adjustments need to be done on the computer as it will not deliver the desired GPA.

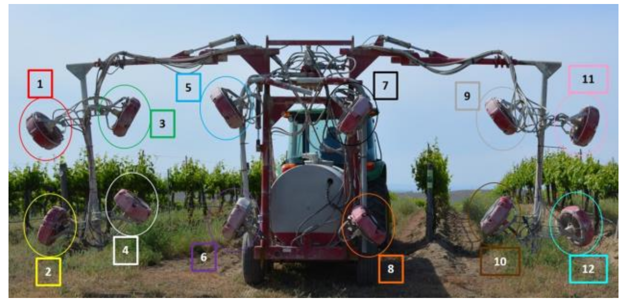


Figure 4: 3-Row Quantum Mist Sprayer equipped with 12 Sardi fans. Notice that the angle of the fans should be directed into the canopy with at least 24" between the canopy and fan.

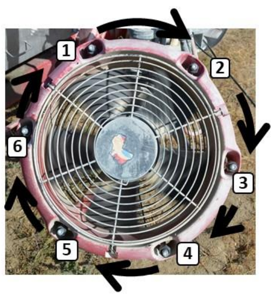


Figure 3: Sardi fan with 6 nozzle bodies. Nozzles should be placed opposite each other, not in serial.

Canopy measurements show the growth of the season, as width increase as this is a modified vsp with more sprawl in the upper canopy (Table 2). Weather stations were used to record basic weather conditions and averages were based on mean data during spray (Table 3). Deposition for canopy and drift are in Table 4 and are represented as the percentage of the total we collected for this sprayer, not total mass balance of all particles released from the sprayer.

Table 2: Canopy measurements for modified VSP.

	Average Width (ft)	Tree-Row-Volume (ft^3/acre)
Early	1.4	7419.7
Late	4.4	57130.2

Table 3: Weather data during collection events. ISO standards were followed

	Temperature (^oF)	Relative Humidity	Average Wind Speed (mph)
Early Full	53.7	68%	6.6
Late Full	71.4	47%	3.3

The lower air volume and opposing fans of the Quantum Mist (QM) sprayer are designed to minimize drift and keep spray within one row. Canopy deposition was high with 95-98% of our collected deposition going into the canopy (Table 4). In both years and times of the season, we saw more deposition in the upper zones of the canopy compared to the lower fruiting zone. We hypothesize that this is because the fruiting zone has far less density of leaves and canopy to catch the spray compared to upper regions. While the fans of the QM have an adjustable speed, they are all adjusted simultaneously. Having independent control of upper and lower fans would could allow the operator to better match the air volume to the canopy in that region. Ground deposition was very low and of the 1.5-3% of the ground deposition, the majority (67-97%) was found in the first row from the sprayed row. Similar results are seen for the aerial deposition. Ground and aerial deposition pattern were similar in both years.

Table 4: Percent of deposition collected in different vineyard areas and more detailed graphics of deposition within that area. Percentages are calculated on amount collected within each area and time of season. These results are specific to yr. 2 collection, but patterns are almost identical to yr. 1 data.

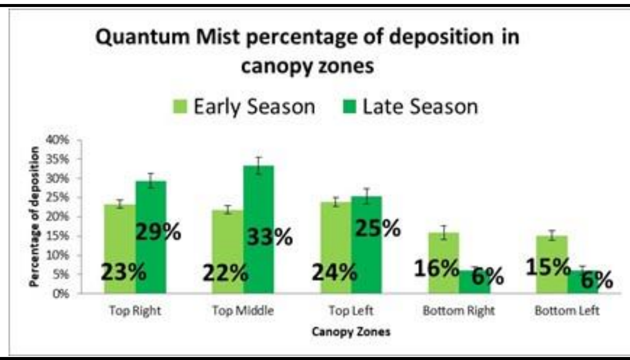
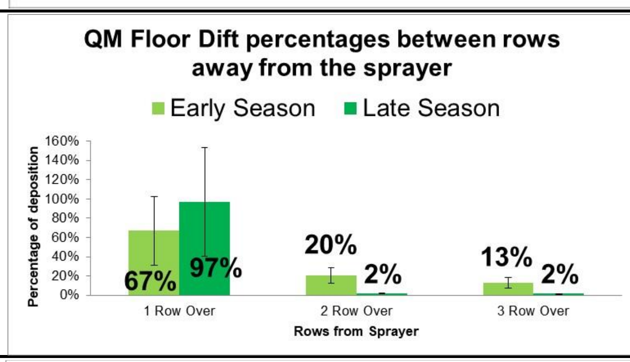
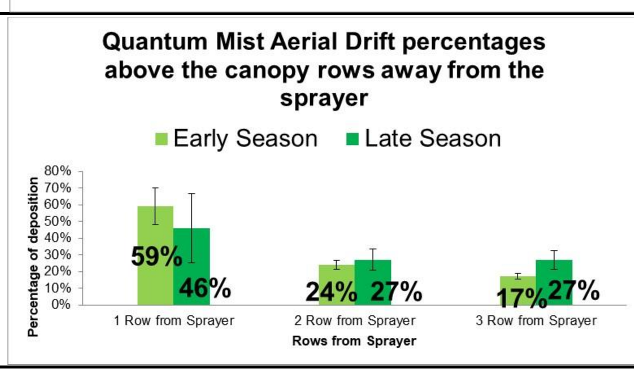
Vineyard Area	Early Season	Late Season	Proportion within each vineyard area
Canopy	95%	98.48%	
Ground	3%	1.51%	
Aerial	2%	0.01%	

Figure 5: 3-Row Gregoire sprayer equipped with 6 wind socks each with 5 pneumatic nozzles. The angle of the fans should be directed into and slightly behind the canopy with 18-24" between the canopy and nozzle.

<u>*Gregoire:*</u> These sprayers are manufactured by Gregoire and sold locally at Blueline Mfg. The sprayer we used was a 3-row machine with 6 wind socks (Fig. 5) that should be 18-24" from the canopy and aimed slightly backwards and into the canopy. Once the bottom of the sock fell off and nozzles were loose, so we recommend checking the socks and nozzles at each tank fill. Each sock as 5 pneumatic nozzles emitting 'very fine' drops (61-105 um), which can be turned on/off in a set of 2 or 3 (Fig. 6). In the early season, we raised the entire boom and aimed the lower three nozzles at the cordon. Later, booms were lowered, and all 5 nozzles were used. Annual inspection should include replacement of rubber gaskets in check valve, cleaning and replacement of leaky hoses, tightening all nuts on nozzles and socks. Pneumatic sprayers are sometimes said to not clog, but we found that poor operations can lead to issues and therefore recommend a triple rinse at the end of an application. There is an in-line disc used in each sock to help with gross measurements of rate and the manufacturer provides a table with recommended disc sizes related to GPA. These should be followed and changed early and late season depending on rate. The rate controller regulates the gallons per minute at a more refined level and verifies speed with a wheel sensor. The sensor is affected by tire pressure/size and speed should be checked manually once per year (for methods go to: http://treefruit.wsu.edu/web-article/six-steps-to-calibrate-and-optimize-airblast-sprayers/). If the rate controller does not match manual verification, then adjustments need to be done on the computer as it will not deliver the desired GPA.

Figure 6: One wind-sock with 5 nozzle bodies that are turned on/off in groups of 3 and 2.

Canopy measurements show the growth of the season, as width increase as this is a modified vsp with more sprawl in the upper canopy (Table 5). Weather stations were used to record basic weather conditions and averages were based on mean data during spray (Table 6). Deposition for canopy and drift are in Table 7 and are represented as the percentage of the total we collected for this sprayer, not total mass balance of all particles released from the sprayer.

Table 5: Canopy measurements for modified VSP.

	Average Width (ft)	Tree-Row-Volume (ft^3/acre)
Early	1.1	6548.5
Late	4.4	57130.2

Table 6: Weather data during collection events. ISO standards were followed

	Temperature (^oF)	Relative Humidity	Average Wind Speed (mph)
Early Full	65.7	68%	2.1
Late Full	84.5	32%	2.9

Like the QM, the lower air volume and directions of spray are designed to minimize drift and keep spray within one row. Canopy deposition was high with 97% of our collected deposition going into the canopy (Table 7). In the early season, more deposition was in the lower canopy near the cordon. This is appropriate as we were able to use only three nozzles directed at the cordon. Our collector cards for the upper canopy would be in a zone well above the cordon. Later in the season, a more even distribution was seen between the upper and lower zones of the canopy, however, in the first year, there was more deposition in the upper canopy (~75%), matching the patterns of QM. The annual differences could be due to different sprayers or adjustments as individual nozzle output can sometimes vary widely in pneumatic sprayers. Ground deposition was again very low and of the ~2.5% of the ground deposition, the majority (90-95%) was found in the first row from the sprayed row. Similar results are seen for the aerial deposition. Ground and aerial deposition pattern were similar in both years.

Table 7: Percent of deposition collected in different vineyard areas and more detailed graphics of deposition within that area. Percentages are calculated on amount collected within each area and time of season (early/late).

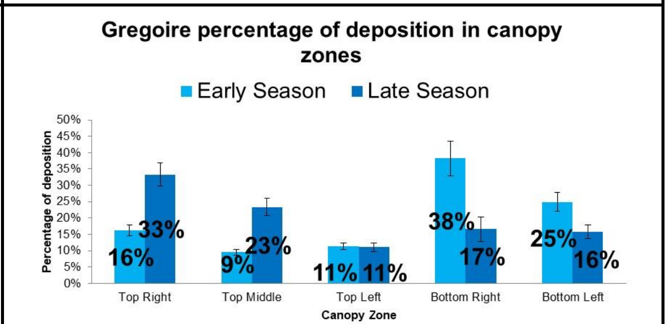
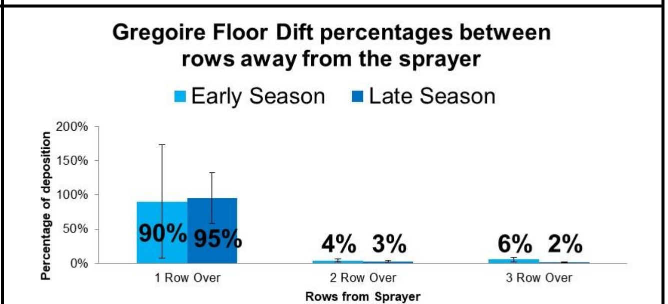
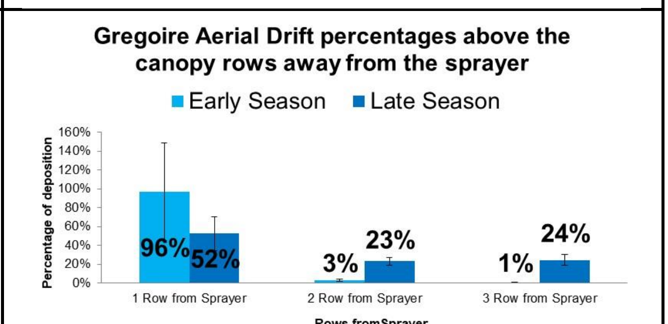
<table>
<tr><th>Vineyard Area</th><th>Early Season</th><th>Late Season</th><th>Proportion within each vineyard area</th></tr>
<tr><td>Canopy</td><td>97.3%</td><td>97.1%</td><td>
</td></tr>
<tr><td>Ground</td><td>2.6%</td><td>2.8%</td><td>
</td></tr>
<tr><td>Aerial</td><td>0.1%</td><td>0.1%</td><td>
</td></tr>
</table>

Figure 7: 2-Row On Target Electrostatic sprayer equipped with 8 tubes each with 5 pneumatic nozzles each. The angle of the tubes should be directed into the canopy with 18-24" between the canopy and nozzle.

<u>*On Target:*</u> These sprayers are manufactured by On Target Spray Systems. The sprayer we used was a 2-row machine with 8 tubes (Fig. 7) that should be 18-24” from the canopy. Each set of tubes (Fig. 8) emits ‘very fine’ drops (61-105 um). Electrostatic sprayers emit a charged droplet. The smaller the droplet, the stronger the charge. Since these are a form of air-shear nozzle, they should be run at low volumes (20 GPA) to ensure smaller droplets. The charge exists but is a weaker charge and most effective when within 2 cm of the plant tissue. Misconceptions include that these can be run at high GPA without the charge, the spray will be sucked back to the plant because of the charge, and they do not need to be cleaned. All of these are wrong and will lead to poor operation of the machine. Annual inspection should include replacement of rubber gaskets, replacement of leaky hoses, checking the charge with a volt meter, and triple rinse at the end of an application.

Figure 8: One set of tubes with-10 nozzle bodies that emit charged particles.

Canopy measurements show the growth of the season, as width increases. This canopy as a tight vsp was narrower than the modified vsp by about 1.5-feet (Table 8). Weather stations were used to record basic weather conditions and averages were based on mean data during spray (Table 9). Deposition for canopy and drift are in Table 10 and are represented as the percentage of the total we collected for this sprayer, not total mass balance of all particles released from the sprayer.

Table 8: Canopy measurements for modified VSP.

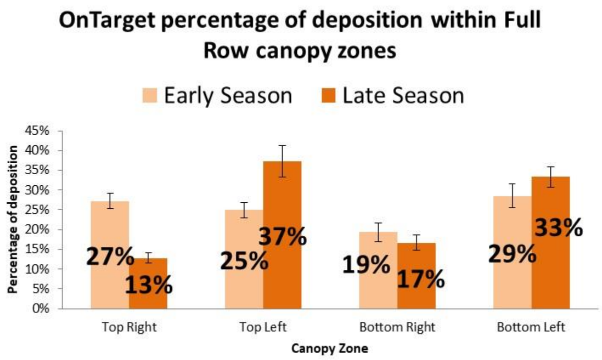
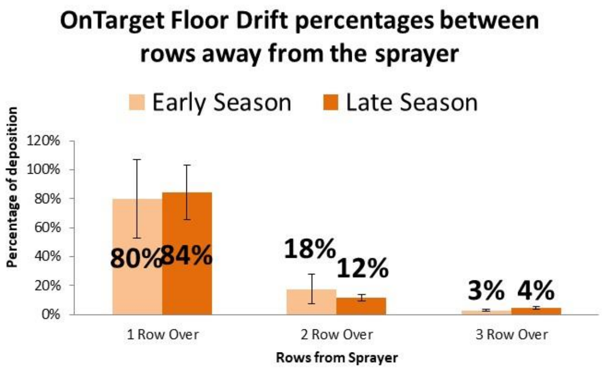
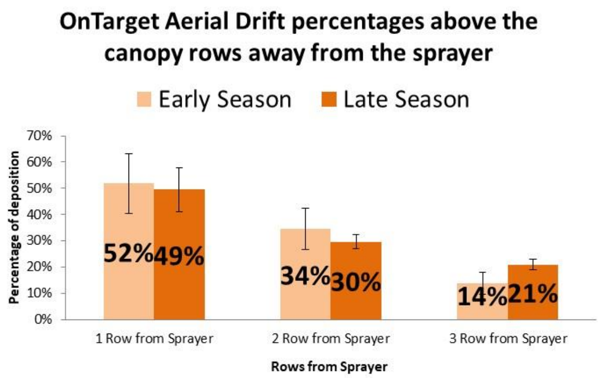
	Average Width (ft)	Tree-Row-Volume (ft^3/acre)
Early	0.93	4999.3
Late	2.97	45469.1

Table 9: Weather data during collection events. ISO standards were followed

	Temperature (^oF)	Relative Humidity	Average Wind Speed (mph)
Early Full	69.8	32%	1.1
Late Full	76.6	37%	6.6

Again, the lower air volume and directions of spray are designed to minimize drift and keep spray within one row. Canopy deposition was high with 80-92% of our collected deposition going into the canopy (Table 10). Deposition was evenly distributed among the nozzles in the canopy. Individual nozzle output can sometimes vary in pneumatic sprayers and may not be consistent among machines. Ground deposition was low and of the 7-16% of the ground deposition, the majority was found in the first row from the sprayed row. Similar results are seen for the aerial deposition. Although well within ISO standards, weather conditions were different for early and late, yet still drift was similar even with a warmer day and 6mph wind.

Table 10: Percent of deposition collected in different vineyard areas and more detailed graphics of deposition within that area. Percentages are calculated on amount collected within each area and time of season (early/late). Canopy did not have an upper middle because it was narrower.

Vineyard Area	Early Season	Late Season	Proportion within each vineyard area
Canopy	91.8%	80%	
Ground	7.4%	16%	
Aerial	0.4%	4%	

Disease Control: Besides the collection events used to measure deposition, sprayers were operated through the entire season over large replicated plots. Field disease ratings were conducted at the end of the season for powdery mildew. There was no difference in season-long disease control among the sprayers (Table 11). Quantum Mist and Gregoire were in the same block, so their disease patterns were similar, compared to On Target. However, since disease severity and location of infection can vary by year and site, these small differences indicate a high level of control from all the technologies.

Table 11: End of season disease ratings. Quantum Mist and Gregoire were in one field and On Target in another. Small differences could be from that, but overall good control was achieved with all sprayers

Sprayer	Zone	Average
Quantum Mist	Cluster	13%
	Fruiting Zone	2%
	Outer Upper	6%
	Inner Upper	5%
Gregoire	Cluster	10%
	Fruiting Zone	2%
	Outer Upper	4%
	Inner Upper	2%
OnTarget	Cluster	7%
	Fruiting Zone	9%
	Outer Upper	14%
	Inner Upper	5%

Airblast and configurations: By request of the committee we performed deposition studies with airblast in 2018 (full canopy) and 2019 (early season). Airblast is still the most used sprayer in the industry. As with any sprayer, determining nozzles type and appropriate air volume for the canopy is critical to minimizing drift and maximizing deposition. Like the others, a poorly operated machine lead to poor spray quality. We studied deposition from 2 nozzles—VisiFlo (same as QM) and Air Induction (AI). VisiFlo are common nozzles emitting droplets with VMD of 61-105 um (very fine). AI nozzles inject air bubbles into droplets creating a coarse (VMD 341-403 um) or very coarse (VMD 404-502) droplet. For perspective, the tip of a human hair is about 100 um and a droplet that small has a higher tendency to drift or evaporate quickly. Larger droplets may not travel as far into taller 20-foot canopies but may be a good alternative for use in airblast in grapes. Lastly, air volume should match the volume of air in the canopy to keep deposition within one row. Replicated trials for nozzle type and air on/off were conducted.

In the top of the canopy, results were comparable among AI-Air Off, VisiFlo Air Off, and VisiFlo Air On (Fig. 9). AI Air On showed lower deposition in the upper canopy and more ground deposition. AI nozzles with the Air Off had significantly more deposition in the fruiting zone. Interestingly, like the Gregoire in year 1 and Quantum Mist, the VisiFlo nozzles showed less deposition in the fruiting zone (bottom) than the upper canopy. Again, suggesting that presence, or lack of canopy, can reduce the possibilities of intercepting and stopping spray.

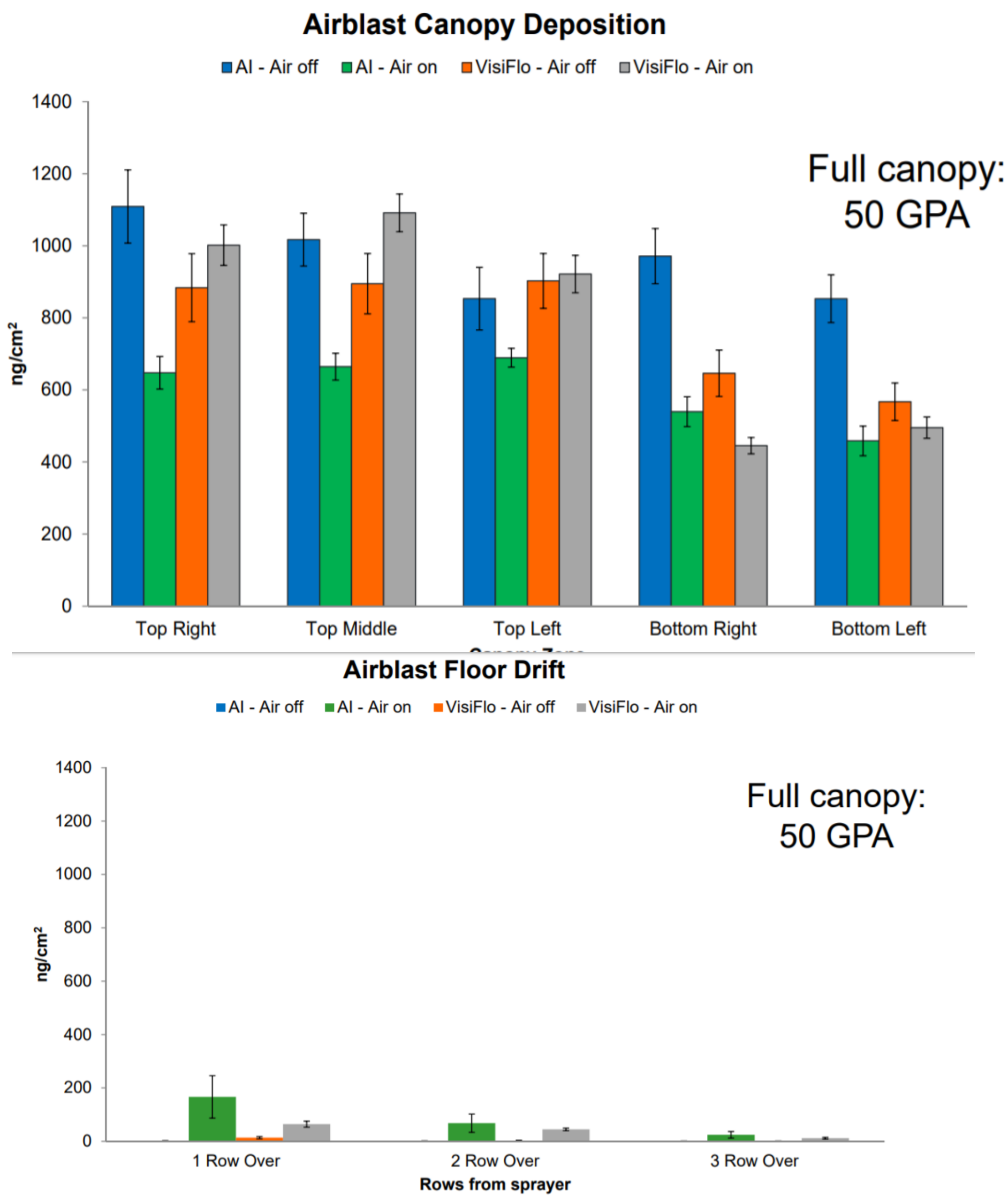


Figure 9: Airblast canopy and ground deposition with 2 nozzles and air on/off. Blue and green are AI nozzles. Orange and grey are VisiFlo nozzles. Deposition was measured in 5 zones of canopy (3 top and 2 bottom) and 1-3 rows from the sprayed row.

<u>Information Dissemination, Extension, and Outreach Activities:</u>

This component of our project is designed to increase adoption of sustainable application technologies and provide a foundation for specialty crop spray application continuing education. It consists of three primary activities: 1) develop recommendations that optimize pesticide deposition in a cost-effective sustainable manner; 2) share with the Spray Application Working

Group (SAWG); and 3) develop curriculum for repeatable in-depth classes for viticulture interns and advisors. Some of the specific activities include:

We have included in this report some specific suggestions that may aid in the operation of these and similarly designed sprayers. We have had nearly 30 presentations/workshops/publications. Three courses have been developed during the time of this grant and 2 have been offered annually. For the newest course, we are collaborating with manufacturers, sponsors and WSDA to conduct our pilot course for Optimization of Alternative Sprayers. July will be the pilot course and it will be offered annually starting in spring 2020. This work has been shared with the SAWG group during our monthly calls. And some of our WA course have been used to model courses being developed for CA fruit growers.

SAWG members from WSDA and myself have developed a 1-day, bilingual Best Management Practice (BMP) sprayer course. It is important to note its format and impact as we are modeling the Optimization of Alternative Sprayers course on this BMP course. Over three years, more than 250 WA farm managers and operators were trained in 10 BMP workshops. In 2017, we conducted a survey of past participants in the BMP class. We only had a 9% response rate of our sample; however, the trainees are often very transient among companies and can be difficult to locate again after several years. Nonetheless, we have consistent trends in our data primarily from tree fruit and grape producers. Additionally, survey results from a broader grape survey were incorporated into these results. Prior to training, only 36-40% of respondents regularly maintained their sprayer components like hoses, pumps, and nozzles, but now after our BMP class 64-69% conduct annual inspections and calibrations. Almost 92% of respondents (a 38% increase) are now using nozzle materials that wear less and improve the accuracy of deposition. Our previous work showed nozzle output on WA sprayers ranged from 43% lower (clogged) to 44% more (worn) than expected. Having a nozzle worn by just 20% can cost an extra $1200/spray for a typical insecticide ($60/acre) on a 100-acre farm. The average acreage owned by attendees is 457 and they are now potentially saving $4800 on each spray. Other improvements have also been made. The percentage of respondents conducting annual checks of their tractor speed has increased from 54% to 94%. Lastly, specific methods used to optimize canopy deposition have also seen about a 30% increase across all different methods (monitoring air direction: pre-38% post 69%; reduce air volume: pre-0% post 33%; looking at spray deposit: pre-1% post 31%). We believe that new courses will continue to have significant impacts.

Posters and Publications

1. Bahlol, H. Y., A. Chandel, G.A. Hoheisel, and L. R. Khot. 2019. Smart spray analytical system for orchard sprayer calibration: a-proof-of-concept and preliminary results. Transactions of the ASABE, ITSC-13196-2018 (Under review).
2. McCoy, M., Hoheisel, G., Khot, L., Moyer, M. 2019. Assessing and Optimizing Sprayer Technologies in Commercial Eastern WA State Wine Grape Vineyards. 21st Annual GiESCO International Meeting. Greece.
3. Bahlol, H.Y., McCoy, M., Hoheisel, G.-A., Khot, L.R. 2018. Comparison of different spray sample collectors for the evaluation of pesticide spray assessment in grapevine. Abstract No. 1801611, ASABE 2018 Annual International Meeting, Detroit, MI, July 29- August 4. Poster Presentation

4. McCoy, M., G. Hoheisel, L. Khot, M. Moyer. 2018. Assessing Airblast Technologies. Washington Association of Wine Grape Growers. Kennewick, WA. Poster Presentation
5. McCoy, M., G. Hoheisel, L. Khot, M. Moyer. 2017. Assessing Sprayer Technology in Washington Vineyards. Washington Association of Wine Grape Growers. Kennewick, WA. Poster Presentation
6. McCoy, M., G. Hoheisel, L. Khot, M. Moyer. 2016. Assessing Sprayer Technology in Washington Vineyards. Washington State Grape Society. Grandview, WA. Poster Presentation
7. Hoheisel, G., and M. Moyer. 2016. Six Steps to Calibrate and Optimize Airblast Sprayers. Viticulture and Enology Extension News. WSU Newsletter article.
8. Bahlol, H., G. Hoheisel, L. Khot, 2016. Smart spray analytical system for orchard sprayer calibration: a-proof-of-concept and preliminary results. ASABE annual meeting. Abstract and Presentation.
9. Hoheisel, G. 2016. This is a Good to Know: Researcher offers five tips from sprayer training workshop. Good Fruit Grower. May.
10. In preparation: Hoheisel, G., Khot, L. Moyer, M. 2017. 6 steps to calibrating an airblast sprayers. WSU Extension Publication

<u>Workshops and Presentations</u>

1. Hoheisel, G. 2019. Update on Application Technology Team. 7th Annual All Agency Pest/Pesticide Issues Forum with Washington Friends of Farms and Forests, Olympia, WA.
2. Hoheisel, G., 2018. Safe Application of Pesticides (Hops, Blueberries), Multi-Commodity Ag Tour. Prosser, WA
3. Hoheisel, G. 2018. New and Advanced Spray Technology. Pesticide Application Safety Work Group, WA Legislature. Quincy, WA. *Invited Speaker*
4. Hoheisel, G., 2018. Update on Federal Sprayer Regulations. National Viticulture Extension Network.
5. Hoheisel, G., 2018. Every Drop to the Crop, SMWE Grower Meeting, Prosser, WA
6. Hoheisel, G., 2018. Sprayer Calibration. Agriculture Safety Day. Wenatchee, WA.
7. Hoheisel, G., 2018. Sprayer Calibration, WSU-NCW Tree Fruit Days Chelan,
8. Hoheisel, G. 2017. Update on Application Technology Team. 5th Annual All Agency Pest/Pesticide Issues Forum with Washington Friends of Farms and Forests, April 26 and May 4, Olympia, WA.
9. Hoheisel, G. 2017. Fruit Spraying in Washington: where we are and need to be. CapstanAG Conference. Topeka, Kansas. *Invited Speaker*.
10. Hoheisel, G., Castagnoli, S., Niederholzer. 2017. Developing a National Spray Application Working Group. 14th Suprofruit International Spray Conference, Belgium. Abstract for oral presentation
11. Bahol, H., Hoheisel, G., Khot, L. 2017. Development and evaluation of an automated vertical spray patternator for calibration of vineyard air assist sprayers. ASABE Annual International Meeting. Spokane, WA.
12. Hoheisel, G. 2017. Prepping Sprayers For Spring. Bleyhl's Farm Service Annual Meeting, Yakima, WA.
13. Hoheisel, G. 2016. Improving your Spray Coverage: The Answer is Blowing in the Wind. Chelan Horticultural Meeting.
14. Hoheisel, G. 2016. BMP's in Sprayer Technology. 2016 Skagit County Blueberry

Workshop.

15. Hoheisel, G. 2016. How the Power of Air Affects Spray Coverage. Great Lakes Expo Annual Meeting. Grand Rapids, Michigan. *Invited Speaker*.
16. Hoheisel, G. 2015&2016. Environmental Conditions and New Technologies. Spray Application Workshop: Improving your Results. 4 separate workshops.
17. Hoheisel, G. and Moyer, M. 2016. Hands-on sprayer calibration and optimization. WSU Western WA Pest Management Workshop. Mt. Vernon, WA. 1-day
18. Moyer, M. 2016. Development of a pesticide program. WSU Western WA Pest Management Workshop. Mt. Vernon, WA. 1-day
19. Hoheisel, G. 2016. Sprayer Best Management Practices. Grape Pest and Disease Management for Western Washington

<u>Curriculum and Courses</u>

1. Hoheisel, G. 2016-present, Best Management Practices for Application Technology, WSU Viticulture and Enology Certificate Program through WSU Global Campus. 4-week course
2. Hoheisel, G., July 2019, Optimizing New Sprayer Technologies (pilot course). 1-day hands-on course
3. Hoheisel, G., O. Borges, J. Ramon, F. Servin. Airblast Sprayer Calibration and Optimization. 1-day hands-on course.