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The role of sprayer design and education in controlling *Erysiphe necator*

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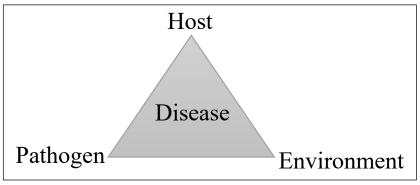
1 Introduction

The well-known disease triangle (Fig. 1) illustrates the interaction of host, pathogen, and environment in both plant and human diseases (Scholthof, 2007). The use of plant protection products with sprayers addresses only the existence or level of the pathogen. Like the disease triangle, chemical control has a triad of aspects impacting efficacy.



Cultural practices, fungicide selection, and sprayer coverage all play an important role in the control of powdery mildew.
Figure 1: Disease triangle indicating the interaction of host, pathogen, and environment

In Washington state (United States), grape powdery mildew, *Erysiphe necator* (syn. *Uncinula necator*) (Schw.) Burr, is the primary fungal disease affecting grapevines. Despite the arid environment in eastern Washington, which is the primary wine grape growing region of the state, grape powdery mildew still requires two to five annual sprays for effective disease control. Cultural control methods, such as canopy management and fruit-zone leaf removal, which focuses on reducing vegetation density in the canopy which improves light penetration and air movement, are complementary to control but rarely provide complete control on their own.

Fungicide applications are the primary recommended management tactic to control *E. necator* and research efforts have strongly supported the develop of new chemistries (Knight *et al.,* 1997; Kunova *et al.,* 2021). In Washington, there are 27 fungicides recommended for control which span 11 different classifications or groups from the Fungicide Resistance Action Committee (FRAC) (Bomberger *et al.,* 2021). However, fungicide resistance in *E. necator* is well documented (Miles *et al.,* 2021; Oliver *et al.,* 2021; Warres *et al.,* 2021) with known or suspected resistant in Washington to FRAC groups 3, 7, 11, and 13 (Bomberger *et al.,* 2021). The remaining fungicide classifications are aryl-phenylketone, inorganic products (e.g., sulfur, oil, potassium bicarbonate), biological products, and plant extracts. Thus, the need to improve coverage is critical for control of *E. necator.* Additionally, poor spray coverage can increase the risk of pesticide resistance selection because of underapplication of active ingredients, or need for additional fungicide applications to compensate for poor disease control (Van Den Bosch *et al.,* 2011; Damicone, 2014).

Broadcast spray application of plant protection products to vine canopies by axial-fan air-blast sprayers has been an effective, yet often inefficient, means of fungicide delivery since the basic design was patented in 1949 (Fox *et al.*, 2008). That design has not been significantly modified in 70 years and still commonly used in many vineyards in Washington and beyond. The original design for air-blast sprayers was for larger tree canopies. Yet as orchard and vineyard canopies have decreased in size, significant off-target drift occurs in orchards and vineyards (Brown *et al.*, 2008; Landers 2008; Grella *et al.,* 2019). Current success in increasing spray coverage and decreasing off-target drift, thereby achieving improved control of *E. necator*, can be attributed to machine design and education on proper sprayer operation.

2 Machine Design

Spray deposition from application technologies is highly influenced by fan size, direction of nozzle body, and nozzle selection. Additionally, those three sprayer components can interact with each other to change spray coverage. Axial-fan air-blast sprayers have nozzle bodies surrounding a large fan. The circular arrangement means that some nozzles, like those pointing up, may not be directed into vineyard canopies depending on the training system. Adaptions to axial-fan air-blast machine design to reduce drift include the use of mini-towers and air induction (AI) nozzles (Fig. 2). The use of AI nozzles decreases drift in vineyards (Derksen *et al.,* 2007, Grella *et al.,* 2017) by increasing droplet size to large (coarse), which do not drift as easily. In eastern Washington vineyards, the use of air induction nozzles without air from an axial fan air-blast sprayer also showed improved canopy deposition (McCoy *et al.,* 2021a).

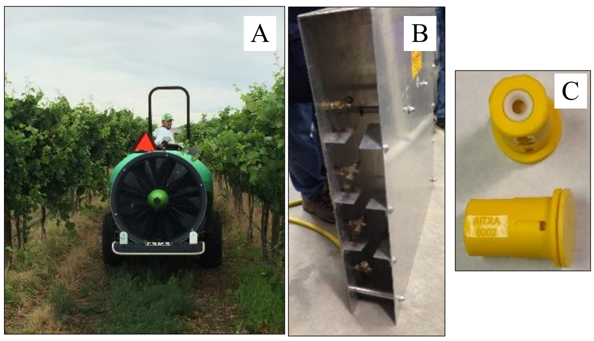


Figure 2: (a) Axial-fan air-blast sprayer with nozzle bodies surrounding the larger single fan, (b) example of a small

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tower adaptor that can be placed on some sprayers to direct spray into the canopy, (c) air induction nozzles create larger, coarser droplets that drift less. They do this by taking in air through the small hole on the side and injecting air bubbles into the spray droplet to increase droplet size.

Reconfiguring sprayers to include designs with less air volume and air/spray directed into the canopy is an additional mechanism used to increase deposition. As important, conidia of *E. necator* is dispersed in wind as low as 5.2 m/s in only 10s (Willocquet *et al.,* 1998) and very high levels of conidia have been detected in vineyards after fungicide applications with an air-blast sprayer (Willocquet and Clerjeau, 1998) that can exceed 9 m/s. Decreasing air volume and speed on sprayer designs has to be a central focus of achieving adequate control.

In eastern Washington, we have evaluated multiple sprayers. They have the commonality that the nozzle bodies are directed perpendicular into the canopy with opposing forces to reduce drift (Fig. 3). Three of the sprayers (Fig. 3 A-C) are pulled by tractors and can be sold as one to five row sprayers. The over-the-row design assists in keeping the air direction targeted into the canopy with opposing forces to keep the spray in the canopy. The multiple small fans or displaced air mean that the air volume is more appropriately matched to the canopy so that spray is not blown through the canopy. The Solid Set Canopy Delivery System (SSCDS) (Fig. 3 D) is a fixed spray system that does not use air for spray delivery, and has nozzles affixed to the drip line to direct spray up into the fruiting zone and canopy.

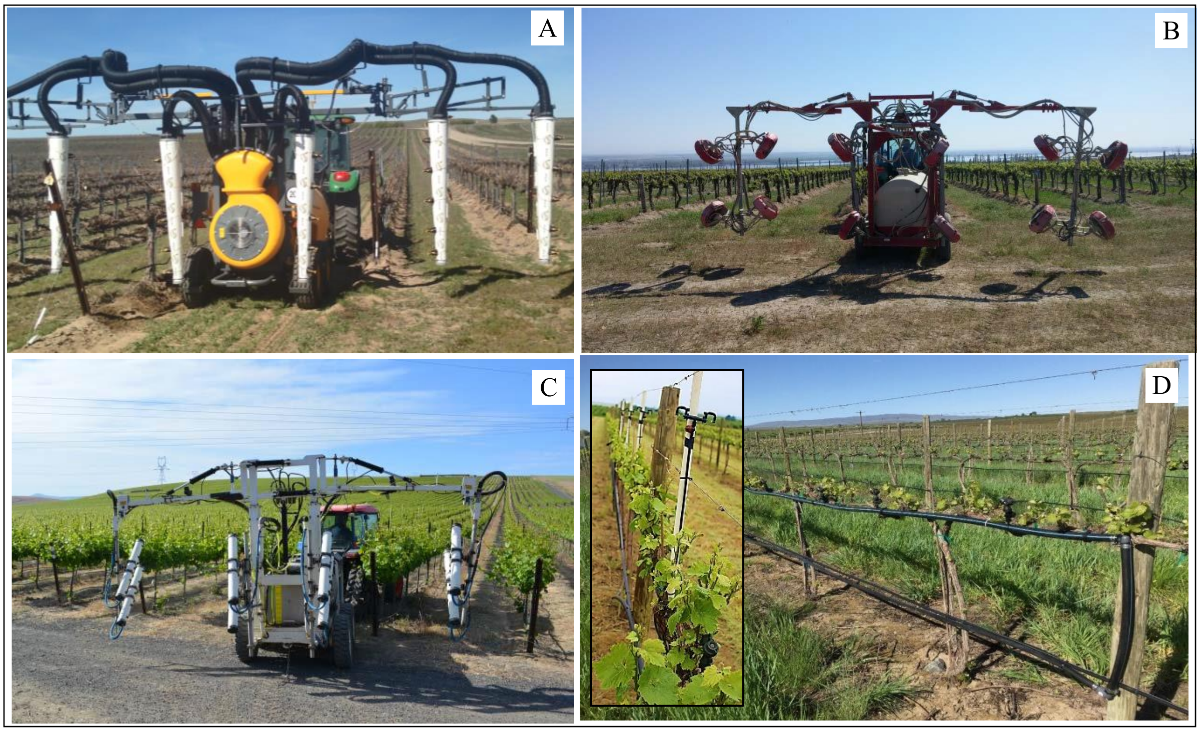

Figure 3: Vineyard sprayers assessed for deposition in Washington, USA vineyards. Three machines—(A) Gregoire, (B) Quantum Mist, and (C) On Target—are commercially available. The (D) Solid Set Canopy Delivery System (SSCDS) is a proof-of-concept fixed spray system installed with disc-core nozzles along the drip irrigation and a separate emitter in the canopy.

Unlike the axial fan air-blast sprayer that showed improved coverage with AI nozzles, these machines are not appropriate for such nozzle. The Gregoire (Fig. 3A) is a pneumatic sprayer that uses high velocity air pushed through fluid to create fine droplets. The Quantum Mist (Fig. 3B) does use exchangeable nozzles but the manufacturer does not recommend use of AI nozzles because of poor coverage seen from demonstrations with water sensitive paper. The On-Target (Fig. 3C) is an electrostatic sprayer that charges fine droplets upon exiting of the machine and the nozzle is fixed. Despite all three of these machines not using the anti-drift AI nozzles, they all showed high deposition in the canopy and very little off target drift with the majority of drift being just one row away from the sprayer (McCoy *et al.* 2021b). Canopy deposition was highest in upper canopy and less so in the fruiting zone. Air dynamics within any canopy is one of the primary influences for deposition patterns (Giametta *et al.,* 2015). Matching the air volume in the canopy with the air volume of the sprayer is a rational for modern sprayer design with multiple air outlets and reduced air volume. In VSP systems, the fruiting zone often has very little foliage and the air volume from these three sprayers may still be more than the sparse fruiting zone causing more 'in-field' drift and reduced deposition. In the SSCDS, the lack of air did lead to less drift, while maintaining deposition in the canopy, yet the trade-off was to align nozzles in below and above the canopy to cover both sides of the leaves (Sinha *et al.,* 2020).

3 Education on Proper Sprayer Operation

Changes in spray application technology create both a need and an opportunity for research and extension to improve targeted spray deposition and reduce drift (Kaine and Bewsell, 2008). Few growers can benefit from the existing and developing body of knowledge on old and new spray technologies. This is likely due to two major challenges: First, there is a lack of comparative data on the relative costs and benefits of new technologies in specific regional and horticultural settings; and second, budget cuts have virtually eliminated extension specialists in perennial crop spray application technology in the US, leaving extension generalists to deliver education in this field. These personnel lack the training necessary to help growers in sprayer operation and calibration, and thus growers lack access to objective, research-based information.

In 2009, the European Union's Directive on Sustainable Use of Pesticides (EU Directive 2009/128/EC) increased regulations for sprayer inspections, education, and use of anti-drift technologies. Although the overall success of the directive is debated (Helepciuc and Todor, 2021), it was considered to be a key point in creating multi-lingual, cross-cultural training in sprayer optimization with more than 400 participants attending trainings. On a much smaller scale, fifteen participants from five US states and one Canadian province participated in one to two, 4-day train-the-trainer workshops. Aimed at county extension educators and farm consultants with little or no knowledge of the engineering aspects of application technology, the course showed participants how sprayers can be adjusted to minimize drift and increase canopy coverage as well as lessons on effective teaching methods. This effort established a national Spray Application Work Group (SAWG) that is small but continues to work jointly on local and regional sprayer education.

One year post training, the number and quality of workshops offered by SAWG members increased. A total of 39 workshops were conducted with 1,577 producers attending, which represented more than 3,642 hectares of fruit and vegetable farms in the United States. Educators also calibrated 86 individual sprayers that would be used on over 2,981 hectares. Trainees in the workshop gave 42 shorter (i.e., 20 to 30 minute) presentations at fruit and vegetable meetings reaching approximately 2,923 producers. Specifically, in Washington state, the educators developed a 1-day, hands-on, bilingual sprayer calibration/optimization course and a 4-week, online course for grape growers. Three years after initiation, nearly 350 farm managers and operators were trained in these two courses, and we conducted a survey of past participants in the 1-day class. Response rate was 9% of trainees, which was lower than desired, but also expected, as attendees are very transient among companies and can be difficult to locate again after several years. Nonetheless, there are consistent trends in the survey results. Prior to training, only 36-40% of respondents regularly maintained their sprayer components like hoses, pumps, and nozzles, while 64-69% conduct annual inspections and calibrations after the training. Almost 92% of respondents (a 38% increase prior to the class) use nozzle materials that wear less and improve the accuracy of deposition. 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%).

Our previous assessment of 20 random fruit sprayers in Washington measuring output of individual nozzles, showed nozzle output ranged from 43% lower (clogged) to 44% more (worn) than expected from the manufacturer. Having a nozzle worn by just 20% could cost an extra $6,000 USD /spray on a 40-hectare farm with a typical spray costing $150-250 USD /hectare in fruit crops (Gallardo and Galinato, 2021). A clogged nozzle can also equate to poor disease control, and crop loss related to powdery mildew infection, and additional selection pressure for fungicide resistance.

4 Conclusions

Controlling grape powdery mildew is a multi-faceted approach, that combines the understanding of pathogen and host biology, environmental influences on those, and efficacy of chemical and cultural approaches. However, chemical approaches are more than just product selection. If improperly applied, chemicals have reduced efficacy that can lead to poor disease control and fungicide resistance selection. There are commercial technologies that improve coverage but understanding proper function and operation for each machine is critical. Education plays an important role in improving sprayer use and thus disease control, but capacity to deliver that education is needed in the United States, and the capacity and need for education likely should be evaluated elsewhere as well.

References

1. Bomberger, R., Black, C., Hoheisel, G., Miller, T., Moyer. M., Rayapati, N., Zasada, I., Walsh, D. 2021. Pest Management Guide for Grapes in Washington. Hoheisel, G. and Moyer, M. (Editors). Pp.62. Washington State University Extension. EB0762.
2. Brown, D.L., D.K. Giles, M.N. Oliver, P. Klassen. 2008. Targeted spray technology to reduce pesticide runoff from dormant applied orchards. *Crop Protection,* 27, 545-552.
3. Damicone, J.P., 2014. Fungicide resistance management. Oklahoma State Univ. EPP-7663. Online Dec. 2021 https://shareok.org/bitstream/handle/11244/319916/oksa_epp_7663_2014-02.pdf?sequence=1
4. Derksen, R.C., H. Zhu, R.D. Fox, R.D. Brazee, C.R. Krause. 2007. Coverage and drift produced by air induction and conventional hydraulic nozzles used for orchard applications. *Transactions of the ASABE*, 50(5),1493-1501.

5. DIRECTIVE 2009/128/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. Retrieved November 3, 2021, from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02009L0128-20091125&from=EN
6. Fox, R.D., R.C. Derksen, H. Zhu, R.D. Brazee, S.A. Svenssson. 2008. A history of air-blast sprayer development and future prospects. *Transactions of the ASABE , 51*, (2), 405-410.
7. Gallardo, K. and Galinato, S. 2021. 2019 cost estimates of establishing producing and packing Gala apples in Washington State. WSU Extension Publication. TB18.
8. Giametta, F., Brunetti, L., Romaniello, R. and Bianchi, B., 2015. Experimental tests on a specific machine for distribution of pesticides in vineyards of Apulian Region: size and ecological criteria. In *Proceedings of the 8th International Conference on Environmental and Geological Science and Engineering* (EG'15), 38, 239-246.
9. Grella, M., Gallart, M., Marucco, P., Balsari, P. and Gil, E., 2017. Ground deposition and airborne spray drift assessment in vineyard and orchard: The influence of environmental variables and sprayer settings. *Sustainability*, 9(5), 728.
10. Grella, M., Marucco, P. and Balsari, P., 2019. Toward a new method to classify the airblast sprayers according to their potential drift reduction: Comparison of direct and new indirect measurement methods. *Pest Management Science*, 75(8), 2219-2235.
11. Helepciuc F-E, Todor A (2021) Evaluating the effectiveness of the EU's approach to the sustainable use of pesticides. *PLoS ONE* 16(9), e0256719. https://doi.org/10.1371/journal.pone.0256719
12. Kunova A, Pizzatti C, Saracchi M, Pasquali M, Cortesi P. 2021. Grapevine Powdery Mildew: Fungicides for Its Management and Advances in Molecular Detection of Markers Associated with Resistance. *Microorganisms*, 9(7), 1541. https://doi.org/10.3390/microorganisms9071541
13. Landers, A.J. 2008. Innovative technologies for the precise application of pesticides in orchards and vineyards In: *Aspects of Applied Biology 86. International advances in pesticide application*. pp. 343-348.
14. McCoy, ML., Hoheisel, G.A., Khot, L., Moyer, M.M. 2021a. Adjusting Air-Assistance and Nozzle style for optimized Airblast Sprayer Use in Eastern Washington Vineyards. *Catalyst: Discovery into Practice. Catalyst,* 2021.21001
15. McCoy, ML., Hoheisel, G.A., Khot, L., Moyer, M.M. 2021b. Assessment of Three Commercial Over-the-Row Sprayer Technologies in Eastern Washington Vineyards. *American Journal of Enology and Viticulture*,72 (3), 217-229
16. Miles, T.D., Neill, T.M., Colle, M., Warneke, B, Robinson, G., Sterigiopoulus, I. and Mahaffee, W.F. 2021. Allele-specific detection methods for QoI fungicide resistant *Erysiphe necator* in vineyards. *Plant Disease*, 105, 175-182.
17. Sinha, R., Ranjan, R., Khot, L.R., Hoheisel, G.A. and Grieshop, M.J., 2020. Comparison of within canopy deposition for a solid set canopy delivery system (SSCDS) and an axial–fan airblast sprayer in a vineyard. *Crop Protection*, 132, 105-124.
18. Scholthof, KB. 2007. The disease triangle: pathogens, the environment and society. *Nature Reviews Microbiology* 5, 152–156. https://doi.org/10.1038/nrmicro1596
19. Van Den Bosch, F., Paveley, N., Shaw, M., Hobbelen, P. and Oliver, R. 2011. The dose rate debate: does the risk of fungicide resistance increase or decrease with dose?. *Plant Pathology*, 60(4), 597-606.
20. Warres, B., K. Johnson, K. Busher, C. Cameron, P.M. Brannen, D. Rogers, R. Covington, W. Mahaffee, and T. Neil. 2021. Efficacy of DMI (FRAC 3) fungicides for control of powdery mildew in a DMI-tolerant *Erysiphe necator* population, 2020. *Plant Disease Management*, Rep.15:PF014
21. Willocquet, L. and Clerjeau, M., 1998. An analysis of the effects of environmental factors on conidial dispersal of *Uncinula necator* (grape powdery mildew) in vineyards. *Plant Pathology*, 47(3), 227-233.
22. Willocquet, L., Berud, F., Raoux, L. and Clerjeau, M., 1998. Effects of wind, relative humidity, leaf movement and colony age on dispersal of conidia of *Uncinula necator*, causal agent of grape powdery mildew. *Plant Pathology*, 47(3), 234-242.