

Advancements in Technology for Reduction of Pesticides Used in Orchards and Vineyards

Erdal Ozkan, Professor and Extension State Specialist, Department of Food, Agricultural and Biological Engineering, The Ohio State University

One of the most significant technological advancements for reduction of pesticide use in orchards and vineyards happened more than four decades ago: a rate controller on a sprayer. These gadgets enabled sprayer operators to keep the application rate constant, regardless of changes in ground speed. They are now a standard component on every new sprayer sold. No other significant developments occurred in spray technology for a couple of decades until the introduction of these innovations:

- auto steering and auto guidance of tractors or self-propelled sprayers
- geographic information systems (GIS)
- global positioning systems (GPS)
- pulse width modulation (PWM) nozzle technologies offering alternatives to how farm equipment is operated, including sprayers in orchards and vineyards

Three other new concepts have also come to fruition:

- drones, or unmanned aerial systems (UAS), for a variety of purposes, including spraying in orchards and vineyards
- variable-rate application technology
- site-specific application of pesticides

This fact sheet reviews these three new concepts.

Use of Drones for Spraying

Although not common in the United States, aerial application of pesticides using drones (Figure 1) is becoming a routine activity in other parts of the world. This is especially true in small-acreage Southeast Asian and European vineyards and orchards where the topography prevents spraying by conventional fixed-wing aircraft (Figure 2).



Photo by Santiago Planas, University of Lleida, Spain.

Figure 1. Drones are successfully used in vineyards and orchards for different purposes, including spraying pesticides.



Photo by Flavio Vallenari, iStock.

Figure 2. Drones are gaining popularity in areas where using conventional spraying equipment is neither safe nor practical.



A drone used for spraying is equipped with almost all the parts of a ground sprayer, including a tank and a pump to push pesticides through the hoses to nozzles (Figure 3). Drone spray tank capacity ranges from two to five gallons, and the application rate usually is from 1 to 2 gallons per acre. Depending on the application rate, the spray mixture in the tank lasts 4 to 10 minutes. The maximum flying speed of drones is 15 to 20 miles per hour. Batteries last 5 to 15 minutes, depending on the battery size and type. Some drones can also be programmed to fly to their home base for refueling. After the tank is refilled with the spray mixture, the drone flies back to where it left off and continues spraying. Drones are usually flown manually 9 to 12 feet above the target canopy. As an optional feature, some drones come with a terrain sensor for spraying over uneven terrains. Using this feature, the drone can automatically navigate hills and slopes. The cost of a spraying drone varies between \$5,000 and \$20,000, depending on features such as the size, tank capacity, and battery life.

Currently, several factors contribute to the slow adaptation of drone spraying by growers:

- regulatory requirements by the Federal Aviation Association (FAA), such as obtaining a pilot license to fly drones
- acquiring the skills and experience to fly drones safely
- an FAA mandate requiring a maximum payload capacity (spray volume) less than 55 pounds
- the short battery life of approximately 20 minutes per charge for drones

- a lack of clear instructions and the rates required on pesticide labels when they are applied using drones

Considering the significant interest in and popularity of the idea of drone spraying, these limiting factors are likely to be relaxed and remedied in the future.

Pesticide applicators frequently ask, “Is drone spraying as effective as conventional spraying methods?” The answer for field crop applications is a cautious “yes.” There are a limited number of credible, published reports that show drone spraying is as effective as conventional spraying in field crops like corn, soybeans, and wheat. Unfortunately, very little research is being done to compare the performance (efficacy and drift) of drone sprayers in orchards and vineyards with conventional spraying equipment. However, drones are being used successfully in many parts of the world.

Drones are also used successfully for other purposes in orchards

and vineyards. They are used to collect a wide range of site-specific data, including identifying the presence of weeds to be sprayed, nutrient stress levels, a vineyard’s or orchard’s canopy characteristics (new, old, gaps between vines or trees), areas infested by insects and diseases, and canopy development throughout the growing season. Traditional approaches to collecting such data usually involve laboratory tests and human scouting, which are costly, laborious, and time-consuming tasks. Sometimes, by the time the data is ready for use, it is irrelevant. Moreover, the use of human scouting to analyze field and crop conditions is subjective. Who takes the data—and even the same person taking the data at different times of the day—can affect its quality. Subjective evaluation can lead to poor decisions and huge economic losses. It is very difficult to detect the exact boundaries of the problems and conditions in an orchard or vineyard without having a bird’s eye view of the field from a close distance. Currently this type of data is

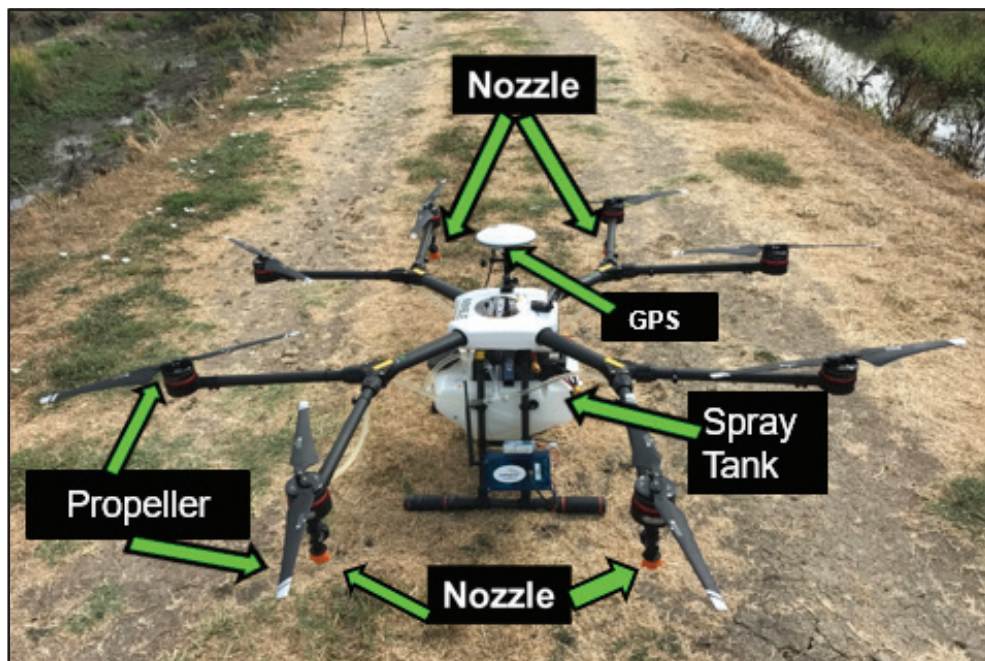


Photo by Ken Giles, University of California-Davis.

Figure 3. Components of a drone sprayer.

collected from satellites that provide multispectral images with about 1 square foot resolution. Sometimes a much higher resolution, like that provided by drones, is needed. With the help of faster and more accurate GPS technology and the availability of high-resolution cameras at a much lower cost, a drone's variable flying speeds and altitudes can provide a wealth of information for every half square inch of crop or soil conditions in an orchard or vineyard.

Site-Specific Spraying

Insects or diseases in a vineyard or orchard are rarely uniformly distributed. In some areas there may be no infestation, light infestation, or very heavy infestation. Also, the type of diseases or insects present may vary from location to location in the same orchard or vineyard. It may be necessary, therefore, to spray different types of pesticides at different rates in different parts of the orchards or vineyards.

Technologies now exist and are being developed for site-specific applications of pesticides. This is a two-step process. First, a prescription map of the area is generated in advance of spraying to identify conditions on the ground, such as canopy characteristics, areas that exhibit nutrient stress levels, or areas infested by insects and diseases that may require pesticide spraying. The map contains GPS coordinates of areas where spraying of different pesticides—or spraying the same pesticide at different rates—may be needed based on the level of pest infestation in the area. The data needed to generate the prescription map with GPS coordinates of the area can be accomplished in several ways:



Photo by Javier Campos, Polytechnic University of Catalonia, Spain.

Figure 4. Site-specific, variable-rate application of pesticides in vineyards and orchards are now a reality.

1. scouting the vineyard and recording the coordinates using a hand-held portable data logger
2. using remote-sensing techniques involving satellite imagery
3. flying small aircraft or drones to take videos or photographs of the orchard or the vineyard

Next, the pictures taken by the cameras are digitized and analyzed, and then a map of the parameters mentioned above is generated. This map is then used to do site-specific spraying by using a drone equipped with spraying components, or a tractor-driven sprayer. Using the data for coordinates of the area to be sprayed, and the GPS technology when the drone or conventional sprayer comes to an area identified as needing spraying by the digitized map, the nozzles are activated to spray. Spraying stops in the no-spray zones that are identified on the digitized map. This process continues until the entire field is sprayed as prescribed by the digitized map. Figure 4 illustrates how a digitized map can be used to spray pesticides in a vineyard according to the needs (a different pesticide at different locations, or changing the application rate) associated with each region separated by a different color throughout a vineyard.

The site-specific application of pesticides described here can significantly reduce the amount of pesticides by following a prescription map developed in advance of spraying.

Variable-Rate Application of Pesticides

In contrast to field crops, a great diversity in canopy structure and density is found in orchards and vineyards. For example, it is a common practice that grapevines of different ages are interplanted in the same vineyard. This creates gaps between grapevines (Figure 5). In addition, the canopy size in the same vineyard varies significantly as the growing season progresses (Figures 6, 7, and 8). This growth rate may be different in different vineyards depending on many factors including soil characteristics and the topography. Unfortunately, today's conventional sprayers do not allow applicators to manually turn nozzles off when there are gaps between vines. Applicators also may not take the time to adjust sprayer settings to match the canopy characteristics (height, size, and shape) of the target vines during spray application. These situations result in much of the sprayed material being wasted, especially during spraying done early in the season when there is very little canopy.



Photo by Javier Campos, Polytechnic University of Catalonia, Spain.

Figure 5. Gaps between grapevines should not be sprayed.



Photo by Javier Campos, Polytechnic University of Catalonia, Spain.

Figure 6. Canopy in early season.



Photo by Javier Campos, Polytechnic University of Catalonia, Spain.

Figure 7. Canopy in mid-season.



Photo by Javier Campos, Polytechnic University of Catalonia, Spain.

Figure 8. Canopy in late season.

Consequently, excessive use of pesticides increases production costs and the potential for environmental contamination. To address these problems, an air-assisted, “intelligent sprayer” was developed in Ohio (Chen, Zhu, and Ozkan 2012; Shen et al. 2017) for variable-rate application of pesticides in orchards, vineyards, and nurseries. This unique spraying system (Figure 9) integrates a high-speed, laser-scanning sensor with a custom-designed, sensor-signal analyzer and variable-rate controller. An integrated spraying system like this can control the duration of the duty cycles (length of time the valve is open) of solenoid valves (Pulse Width Modulation, commonly referred to as PWM) and the flow rates coming through the nozzles attached to the solenoid valves of the multi-channel delivery system. An integrated intelligent sprayer system detects canopy presence; measures canopy size, shape, and foliage density; and then independently controls the spray output of individual nozzles to match the required canopy volume and travel speed in real time. Field tests demonstrated that this sprayer technology can reduce airborne spray drift up to 87%, reduce spray loss onto the ground by 68–93%, lower spray volume by 47–73% (depending on the canopy characteristics at the time of spraying), and effectively control insects and diseases. Currently, one U.S. company (Smart Guided Systems) has commercialized this technology. The company provides components to retrofit existing constant-rate conventional vineyard/orchard sprayers and make them capable of applying pesticides at a variable-rate. This allows growers to modify existing equipment and turn their constant-rate sprayer into a

variable-rate sprayer at a fraction of the cost of a new sprayer.

Unfortunately, some growers are reluctant to invest money in this technology for two main reasons:

1. The price of the components required to convert a fixed-rate sprayer to a variable-rate sprayer is prohibitive. However, economic analysis of owning a variable-rate sprayer shows that for most medium- to large-acreage vineyards, the added cost of the components needed to transform a fixed-rate sprayer to a variable-rate sprayer can be paid off in one year considering the savings in pesticide costs, and the high frequency of spraying done in vineyards or orchards in one growing season.
2. Slow adaptation of the variable-rate spraying technology is also due to the lack of information on pesticide labels that allows growers to use variable-rate technology. However, a number of other factors are

gathering momentum. The information reaching the growers about the short pay-off period of the technology, the focus on reducing pesticide consumption by many countries around the world, and government regulations aimed at reducing environmental pollution associated with use of pesticides will likely cause the variable-rate spraying concept to gain momentum in the future, making it a preferred technology by more growers.

Apps and Software for Effective Spraying and Sprayer Calibration

Several well-designed and credible web-based software programs help orchard and vineyard pesticide applicators spray accurately and efficiently. One is called **Dosavina®**. This software determines the optimum quantity of pesticides and the spray volume rate needed to distribute pesticides uniformly on



Photo by Heping Zhu, USDA-ARS, Wooster, Ohio.

Figure 9: Intelligent variable-rate sprayer developed in Ohio.

vineyards and in other tree and bush crops. It can also be used for nozzle selection and calibration and adjustment of the sprayer. It provides information on optimum as well as practical spraying parameters such as pressure, forward speed, and the best type and size of nozzles for various application situations. Dosavina is available online and is free of charge at dosavina.upc.edu. It is also available as an app on both Android and iOS-format smart phones. Detailed information about Dosavina is available in a 2019 journal article by Gil et al. listed in the reference section of this fact sheet.

The second software, **Dosa3D**[®], estimates the optimal dosage of pesticides based on the spray volume required to meet specific application conditions as dictated by the following parameters:

- the crop being sprayed
- the pests or diseases being controlled
- the product being applied
- the type of spraying equipment being used

Dosa3D shows how dose rates can be lowered when using the more efficient new generation of sprayers, such as tangential flux sprayers in fruit orchards, and vertical booms or recycling sprayers in vineyards. It is available on the web (dosa3d.cat/en) as well as on Android smart phones. Work is in progress to make it available in iOS format. Detailed information about Dosa3D is available in a 2019 journal article by Román et al. listed in the reference section of this fact sheet.

Summary and Recommendations

Regardless of the crop being treated or the equipment used to do it, applying pesticides requires a much higher level of skill and knowledge than all other operations required to grow crops. Because of the nature of the target crop canopy, this is especially the case when spraying fruit trees and grapevines to control insects and diseases. The target to be treated for insect and diseases in vineyards and orchards is completely different than weeds that are visible and fairly uniform in size. With fruit trees and grapevines, the target is above ground and exhibits great variation in height and depth, which makes uniform treatment and coverage difficult.

Technology is advancing to help grape and fruit tree growers apply pesticides more effectively and efficiently. However, regardless of the level of technology and sophistication of the equipment used to spray pesticides, all the conventional, common-sense, and practical aspects of spraying should be kept in mind when applying pesticides in vineyards and orchards. Much of the general rules that apply to all spraying situations are provided in the Ohio State University Extension publication “Best Practices for Effective Spraying in Orchards and Vineyards” (ohioline.osu.edu/factsheet/fabe-539). Here is a summary of some key recommendations from that publication and some final recommendations:

1. Carefully read and follow the recommendations provided on the pesticide label, in the nozzle manufacturers’ catalogs, and in the sprayer operator’s manuals.

2. Choose the right equipment. Choose a sprayer that delivers the required application rate with droplets of the desired size to the target with minimum loss of spray on the ground and in the air.
3. Select the right type and size of nozzle to achieve maximum pesticide deposit and coverage on the target.
4. Calibrate the sprayer to ensure the recommended amount of pesticide based on the product’s label is applied.
5. Understand how to calculate the correct amount of chemical product to mix in the tank.
6. Check the sprayer setup to ensure that the pesticide is distributed evenly on all parts of the canopy.
7. If more than one type of chemical is added to the sprayer tank, check the products’ labels to ensure mixing is done in the appropriate order.
8. Operate the nozzles at a pressure that allows them to produce the spray quality (droplet size) recommended on the product label.
9. Keep spray drift in mind. Take precautions to reduce it to minimum. Consider using drift-reduction nozzles.
10. Slow down when spraying. Spray coverage at the inner parts of the vines is usually improved at slower speeds. Travel speeds that are too slow, however, are likely to result in excessive use of pesticides and increased spray drift.

11. Take advantage of technological advancements in spray technology, such as variable-rate and site-specific application that reduces pesticide consumption.
12. Utilize apps developed by sprayer/nozzle manufacturers to select the best nozzle type and size for a specific application situation.
13. Utilize educational resources and software, such as Dosavina® and Dosa3D®, to help you determine the optimum quantity of pesticides, and the spray volume rates needed to distribute pesticides uniformly on vineyards based on canopy conditions and grape production methods. They are also helpful for nozzle selection, and sprayer calibration and adjustment.
14. Conduct tasks such as sprayer calibration and mixing and loading of chemicals in areas that do not have ground and/or surface water pollution.
15. Be safe. Wear protective clothing, goggles, rubber gloves, and respirators as recommended on the product's label when calibrating the sprayer, doing the actual spraying, and cleaning the equipment.
16. The following websites are excellent sources of additional information on spraying orchards and vineyards:
 - platform.innoseta.eu/
 - sprayers101.com/airblast101/

Acknowledgment

The author thanks the following individuals for reviewing this publication and offering valuable comments: Dr. Dee Jepsen, Professor at Food, Agricultural and Biological Engineering, The Ohio State University; Dr. Emilio Gil, Professor at Polytechnic University of Catalonia, Spain; Dr. Javier Campos, Dr. Carla Román, and Dr. Ramón Salcedo, visiting researchers from Spain to the Dept. of Food, Agricultural, and Biological Engineering, The Ohio State University; Tim Vargo, technical editor and Tim Bowman, graphic designer, both at College of Food, Agricultural, and Environmental Sciences, Ohio State University Extension Publishing.

References

Chen, Yu, Heping Zhu, and Erdal Ozkan. 2012. "Development of a Variable-Rate Sprayer with Laser Scanning Sensor to Synchronize Spray Outputs to Tree Structures." *Transactions of the ASABE*, Volume 55, Issue 3: 773–781. DOI:10.13031/2013.41509.

Gil, Emilio, Javier Campos, Paula Ortega, Jordi Llop, Anna Gras, Enric Armangol, Ramon Salcedo, and Montserrat Gallart. 2019. "DOSAVIÑA: Tool to Calculate the Optimal Volume Rate and Pesticide Amount in Vineyard Spray Applications Based on a Modified Leaf Wall Area Method." *Computers and Electronics in Agriculture*, Volume 160, May 2019: 117–130. doi.org/10.1016/j.compag.2019.03.018.

Ozkan, Erdal. 2022. "Best Practices for Effective Spraying In Orchards and Vineyards" (FABE-539). *Ohioline*, The Ohio State University. ohioline.osu.edu/factsheet/fabe-539.

Román, Carla, Miquel Peris, Joan Esteve, Miguel Tejerina, Jordi Cambray, Pere Vilardell, and Santiago Planas. 2022. "Pesticide Dose Adjustment in Fruit and Grapevine Orchards by DOSA3D: Fundamentals of the System and On-Farm Validation." *Science of the Total Environment*, Volume 808, February 20, 2022: 152158. doi.org/10.1016/j.scitotenv.2021.152158.

Shen, Yue, Heping Zhu, Hui Liu, Yu Chen, and Erdal Ozkan. 2017. "Development of a Laser-Guided, Embedded-Computer-Controlled, Air-Assisted Precision Sprayer." *Transactions of the ASABE*, Volume 60, Issue 6: 1827–1838. DOI:10.13031/trans.12455.