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Best Practices for Effective Spraying In Orchards and Vineyards

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Regardless of the crop being treated, or the equipment used to do it, applying pesticides requires a much higher level of skill/knowledge than all other operations required to grow crops. This is especially the case when spraying fruit trees and grapevines for insect, disease, and mite control. Grapevines and fruit trees are challenging because of their wide variations in canopy characteristics (type, depth, height, and row distance) and the need to spray with sufficient momentum to reach the grapevine's near side, far side, top, and bottom. For this reason, vineyard and orchard spraying requires a higher degree of knowledge and management skills than what is required to spray field crops.

Although each crop requires a slightly different approach to the application of pesticides, some general principles apply to almost all spraying situations, including fruit trees and grapevines:

1. Identify the pest(s) and make decisions on the need for spraying that consider the damage thresholds.

2. Select the pesticide designed to control the identified pest(s).
3. Select the proper spraying equipment, particularly the correct type and size of nozzle.
4. Apply the pesticide at the right time and under the right conditions.
5. Check the accuracy of equipment periodically to ensure that the correct amount of pesticide recommended on the pesticide label is being applied and distributed uniformly onto the target.

When applying pesticides, certain tasks are required for maximum biological efficacy:

1. Mix pesticides uniformly (especially dry products) in the sprayer tank. This can be accomplished only if the agitation system has sufficient capacity for the size of the tank and is operating properly.
2. Choose a pump with sufficient capacity to deliver the required gallonage (gal/acre) to the nozzles.
3. Ensure that hoses and fittings between the pump and nozzles are properly sized to minimize pressure losses.
4. Ensure that there is a minimum loss of pesticides as they are sprayed from the nozzles to the target.



5. Attain a maximum retention of droplets on the target (minimum rebound).
6. Provide thorough and uniform coverage of the target with droplets that carry active ingredients.

The following information is a summary of the most critical issues affecting the effective and efficient application of pesticides in vineyards.

Choose the Right Equipment

Different types of sprayers are used for treating pests (weeds, insects, and diseases) in vineyards and orchards because of variations in:

- canopy structure and characteristics (height, depth, density).
- the width of the distance between rows of canopy.
- the size of the area treated (from smaller than an acre to hundreds of acres).

The most important factors for selecting a vineyard or an orchard sprayer are that it delivers the required application rate, sprays droplets of the proper size on the target uniformly, and minimizes the loss of spray on the ground and in the air.

The following sections provide a brief introduction of the types of sprayers used in vineyards. Extensive information on vineyard and orchard sprayers is available in Ohio State University Extension publication (FABE-533) “Sprayers for Effective Pesticide Application in Vineyards” (ohioline.osu.edu/factsheet/fabe-533).

Depending on the size of the vineyard or orchard and conditions of the canopy, one type of spraying equipment may be preferred over others. Generally, the sprayers used in vineyards fall into two types: hydraulic and pneumatic.

Hydraulic Sprayers

There are three types of hydraulic sprayers:

Manually operated sprayers (hand pumps, hand cans, and backpacks)

Manually operated backpack sprayers (Figure 1) are used mostly for spot treatment and for spraying smaller areas in orchards and vineyards. Although they are small, two general rules of application accuracy also apply to manual sprayers:

- Maintain a consistent walking speed to keep the application rate relatively uniform throughout the operation.
- Maintain the same spraying pressure to keep the application rate and the droplet size uniform during the application.



Javier Campos, Polytechnic University of Catalonia, Spain

Figure 1. Backpack sprayer with a lance.

Hydraulic sprayers with vertical boom (no air assistance)

Hydraulic sprayers with a vertical boom (Figure 2) are very similar in design to the hydraulic sprayers used for spraying field crops like corn, soybean, and wheat. The main difference is that vineyard and orchard sprayers have a vertical boom and field crop sprayers have a horizontal boom. Hydraulic vineyard and orchard sprayers also have higher spray pressure to help droplets penetrate the dense grapevine canopy. Nevertheless, in spite of using higher pressures, the droplets from hydraulic sprayers don't effectively penetrate the inner parts of the canopy.



Javier Campos, Polytechnic University of Catalonia, Spain

Figure 2. Sprayer with vertical boom and conventional nozzles.

Air-assisted sprayers

Most of the sprayers used in vineyards are in this category. With these sprayers (Figure 3) air generated by a fan is directed toward a liquid spray discharge system pointed toward the canopy. Droplets are blown by the air from nozzles pointed at the target canopy. The air blown toward the canopy separates

the canopy's leaves. This leaf separation creates more open spaces for droplets to penetrate deeper into the canopy, resulting in improved coverage of pesticides throughout the canopy. Liquid spray distribution from air-assisted sprayers is significantly influenced by the airflow pattern in the vineyard or orchard. Therefore, the right type of air-assisted sprayer should be selected based on the canopy conditions in the vineyard or orchard.

Although the air-assisted sprayer type shown in Figure 3 is the type used by most grape growers in the U.S., many other, more efficient types of air-assisted sprayers are used in other parts of the world. More information on these types of sprayers is available in the Ohio State University Extension publication (FABE-533) "Sprayers for Effective Pesticide Application in Vineyards" (ohioline.osu.edu/factsheet/fabe-533).



Erdal Ozkan, The Ohio State University

Figure 3. Air-assisted sprayer.

Pneumatic air-shear sprayers

The fine droplets produced by these sprayers (Figure 4) are not created by a nozzle operated under high pressures as is the case with other air-assisted hydraulic sprayers. Pneumatic air-shear sprayers have



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Figure 4. Tree-point-hitch air-shear sprayer.

a low-pressure liquid emitter inserted into the exit port of a venturi tube. Air generated by a fan passes through the venturi tube, then discharges the liquid from the emitter, where it is sheared into extremely fine droplets that are directed at the target. Because the liquid is turned into very small droplets, the spray volume applied per acre is significantly reduced compared to the airblast sprayers. But the very small droplet size produced by pneumatic sprayers also means that low relative humidity, high temperatures, and windy conditions can adversely affect the efficiency of the spray application process while further exacerbating the airborne drift.

Select the Right Type and Appropriate Size of Nozzle

Although nozzles are some of the least expensive components of a sprayer, they hold a high value in their ability to influence sprayer performance. Nozzles meter the amount of liquid sprayed, emit the desired spray pattern, and influence the droplet size. The droplet size is a critical factor when it comes to the spray penetrating into the target, providing a uniformity of coverage on the target, and minimizing the risk of spray drift. The best nozzle for a given application maximizes the pesticide's efficacy, minimizes spray drift, and complies with label requirements such as the application rate (gallons per acre) and spray droplet size.

Nozzles come in a wide variety of types and sizes. Sprayers used in orchards and vineyards are usually equipped with hollow cone nozzles (Figures 5–6). Although not common in the U.S., flat fan nozzles (Figure 7) and "low drift" cone nozzles are becoming as popular as hollow cone nozzles in other parts of the world—especially Europe—for use mostly in orchard sprayers.

Once the best nozzle type is determined, select the nozzle size that complies with the application rates (gallons per acre) prescribed by the product label for various operating conditions (spray



Figure 5. Disc-core hollow cone nozzle.



Figure 6. One-piece, hollow cone nozzle.



Figure 7. Flat fan nozzle spray pattern.

pressures and travel speeds). Apps developed by most of the major nozzle manufacturers can provide the exact nozzle flow rate required for any given set of application parameters and recommend nozzles for the given application parameters. To find these apps, visit your smart phone's or tablet's store and search "spray nozzle calculator" or some other key words related to nozzle size selection. Searches using the name of nozzle companies may also produce app results. However, some apps are not user-friendly and do not account for droplet size requirements when recommending nozzles. Although the apps and tables in catalogs may expedite the nozzle size selection process, it is recommended that spray applicators understand the procedure and math that nozzle manufacturers use to generate table values in their catalogs and nozzle recommendations in their apps. The procedure for nozzle selection and additional information is available in Ohio State University Extension publication (FABE-534) "Selecting the Right Type and Size of Nozzles for Effective Spraying in Orchards and Vineyards" (ohioline.osu.edu/factsheet/fabe-534).

Keep Spray Drift in Mind When Spraying

For many reasons, including production costs, safety, and the environment, it is important to maximize pesticide deposits on the target when spraying pesticides. Spray drift is a major challenge to pesticide applicators trying to achieve this goal. Spray drift is defined as wind moving a pesticide from the application site to an off-target site, as shown in Figure 8.

Drift can occur during spraying and even after spraying as a result of the volatilization of pesticides.



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Figure 8. Spray drift becomes even a more serious concern when application is performed under windy conditions.

Both situations move pesticides away from the application site. Vapor drift from volatilization of pesticides, however, poses a relatively low risk of injury to nearby sensitive crops compared to the physical movement of spray droplets outside the intended application site.

The creation or reduction of spray drift is impacted by various factors:

- spray characteristics, such as volatility and viscosity of pesticide formulation
- equipment (especially the nozzles) and application techniques used for spraying pesticides
- weather conditions at the time of application, including wind speed and direction, temperature, relative humidity, and stability of air around the application site
- operator care, attitude, and skill

Although complete elimination of spray drift is impossible, it can be significantly reduced by being aware of its major causative factors and by taking precautions to minimize their influence on off-target movement of droplets. Extensive information related to factors influencing spray drift is in the Ohio State University Extension publication (FABE-525) "Effect of Major Variables on Drift Distances of Spray Droplets" (ohioline.osu.edu/factsheet/fabe-525).

Here are some of the most cost-effective and practical ways to minimize spray drift:

1. Nozzles play a significant role in either generating spray drift or reducing it because nozzles determine the size of droplets. Droplets classified as fine (F) and extremely fine (EF) are susceptible to drift. It is prudent, therefore, to choose nozzles and operate the sprayer in conditions that minimize the generation of extremely fine and fine droplets.
2. Spray pressure affects the size of droplets released from a nozzle. Higher pressure produces smaller droplets. Therefore, avoid operating the sprayer at high pressures.
3. Spraying in high winds, high temperatures, and low relative humidity increases the risk of spray drift. If weather conditions are not favorable and there is a concern that spraying might result in drift, wait for more favorable conditions. Carry a small handheld, battery-powered wind meter (anemometer) to check the wind speed several times before and during spraying.
4. Pay attention to atmospheric surface-inversion conditions. Under stable air conditions, a warm air layer at some distance overhead may act like a blanket, holding down cooler air underneath. This phenomenon is referred to as atmospheric

inversion. Particles suspended in the cool layer, including vaporized pesticide active ingredients, cannot move anywhere except laterally, possibly for several miles. Avoid spraying when the air is calm and the chances of an inversion are high. Usually, clear nights combined with no wind, increase the chance of inversion, especially early in the morning.

5. After the wind speed, too much air from the sprayers is usually the biggest contributor to drift. Adjust the sprayer fan airflow rate and volume so the air being directed into the canopy replaces the air already in the canopy but dies down significantly as it reaches the other side of the canopy.
6. Carefully direct the air from the fan toward the canopy to ensure the sprayed droplets cover the canopy. With conventional airblast sprayers, deflector plates must be installed on both the top and the bottom of the fan, and on both sides of the sprayer, to guide the spray plume.
7. The travel speed of the sprayer also influences spray drift. Slow travel speeds allow the canopy to be exposed to the air flow for a much longer time period, thus contributing to drift. However, traveling too fast is also not recommended because the air doesn't have adequate time to penetrate inside the canopy, displace the air inside the canopy, and reach the other side of the row. This results in inadequate spray deposition on the outer edge of the row, which reduces protection against insects and diseases. Some studies indicate that the best results are achieved when the travel speed is between 2.5 to 4 mph.
8. When spraying the outer side of the last row, turn off the nozzles that are pointed away from the canopy. In addition, if you are using a conventional airblast sprayer with radial air discharge, cover the air exit port on the side of the sprayer facing away from the canopy. Both of these actions reduce drift risk.

More information on minimizing spray drift is available in the Ohio State University Extension publication (FABE-535) "Strategies to Minimize Spray Drift for Effective Spraying in Orchards and Vineyards" (ohioline.osu.edu/factsheet/fabe-535).

Maximize Pesticide Deposit and Coverage on the Target

To achieve effective pest control, choose the nozzle and set up the application equipment based on what pest is being controlled and the part of the plant canopy that is being targeted. For example, a target may be the grape

clusters, not the grape leaves. For better deposition and to save pesticides, make sprayer adjustments, such as turning on only the nozzles that provide coverage on the zone of the grapevine where the grape clusters are located.

Adequate amounts of pesticide being sprayed on the target is only one aspect of efficient pesticide application. An equally important aspect is how efficiently and uniformly the target is covered. The term used to describe this is "spray coverage." The goal in spraying fungicides and insecticides should be landing as many droplets on the target as possible (maximum coverage). This is one reason why nozzles producing fine to medium droplets are preferred in general, especially when using air-assisted sprayers.

The most practical and easy way to determine the location and uniformity of pesticide application is to use water-sensitive papers attached to leaves in different locations of the canopy (depth, height).

These water-sensitive papers should also be affixed to the upperside and underside of leaves, as shown in Figure 9. Check the coverage on these cards after spraying pesticides. Spray droplets intercepted by the yellow water-sensitive cards leave a blue stain, representing the spray deposit and coverage.

No deposit on the cards indicates that the pesticide is not reaching that area of the vine. Spray coverage is usually expressed in either percent of the card covered with droplet stains or the number of droplet stains on one square inch of the card. Each is an important measure of spray coverage, and both should be taken into consideration when assessing spray coverage. Although the recommendation for optimum coverage varies depending on the target being sprayed (generally fungicides require a higher coverage rate), a spray coverage of 25% to 35%, or 450 to 600 droplet stains per square inch of the card represent adequate coverage for most spray applications. Cards covered with more blue stains than what is shown in Figure 9 indicate that pesticides are being wasted.

More information on improving spray coverage and deposition is available in the Ohio State University Extension publication (FABE-536) "Maximize Pesticide Deposit and Coverage on the Target for Effective Spraying in Orchards and Vineyards" (ohioline.osu.edu/factsheet/fabe-536).



Emilio Gil, Polytechnic University of Catalonia, Spain

Figure 9. A water-sensitive card after the spraying is done. This represents ideal coverage of the target sprayed.

Calibrate the Sprayer to Determine the Actual Application Rate

A sprayer can only be effective, efficient, and safe if properly checked and calibrated before the sprayer is taken to the field, and if it's periodically checked and calibrated during the spraying season. The primary goal with calibration is to determine the actual rate of application (usually in gallons per acre), and then to make the necessary adjustments if there is a difference greater than 5% between the actual application rate and the intended application rate.

Before calibration, run the sprayer, inspect it for leaks, and make sure all vital parts function properly and that the sprayer has a good set of nozzles. While some nozzles or screens may become clogged and cause under-application, other nozzles may be overspraying because of wear. Check the flow rate of each nozzle for at least 30 seconds and then replace the old nozzles with new nozzles to compare the flow rate of the new nozzles and the old nozzles, using the same pressure setting recommended by the manufacturer's catalog or website. Replacing a nozzle is recommended if an old nozzle has a measured flow rate that is 10% greater than that of the new nozzle.

Once all the nozzles on the sprayer are checked to make sure they are not clogged or worn out, the sprayer is ready for calibration. Two key measurements are needed to calibrate a sprayer:

- actual ground speed
- nozzle flow rate



Erdal Ozkan, The Ohio State University

Figure 10. Hoses should be connected securely to each nozzle to determine the flow rate.

Checking the flow rate of nozzles without getting wet (sprayed) during the process requires special care. Be sure to securely attach hoses to each nozzle and collect the nozzle output as shown in Figure 10. There are clamps specifically designed to attach hoses to the nozzles. A much cheaper option is to use milking liners as shown in Figure 10.

For safety reasons, calibration should be done using water in the sprayer tank. Even when calibrating the sprayer using water, always wear the personal protective equipment used for spraying pesticides, such as gloves and goggles. More information on calibrating orchard and vineyard sprayers is available in the Ohio State University Extension publication (FABE-537) “Calibration of Orchard and Vineyard Sprayers” (ohioline.osu.edu/factsheet/fabe-537).

Understand How to Calculate the Correct Amount of Chemical to Mix in the Tank

Although a sprayer may be in good condition and calibrated frequently, if the correct amount of chemical is not put into the sprayer's tank, an application of pesticide on a vineyard or orchard can result in unsatisfactory pest control. Pesticide labels list two recommended application rates:

- volume of spray mixture (pesticide and water) applied per unit area (usually gallons per acre which is written as gal/acre)
- amount of actual chemical applied per unit area (usually ounces, pints, or quarts per acre)

The first recommendation—volume of spray per unit area (gal/acre)—is attained through proper calibration and operation of the sprayer. The second label recommendation requires not only proper calibration and operation, but also the right concentration of the actual product applied.

The amount of chemical needed per tankful depends on the recommended rate and the size of area that can be treated per tankful of spray. Calculations and concepts are the same whether using a manual backpack sprayer with a five-gallon tank or a tractor-driven sprayer with a 500-gallon tank. The only difference is in units, such as ounces, pints, or quarts per acre. Detailed information on how to calculate the proper amount of chemical to add to the spray tank is provided in the Ohio State University Extension publication (FABE-530) “How Much Chemical Product Do I Need to Add to My Sprayer Tank” (ohioline.osu.edu/factsheet/fabe-530).

Take Advantage of Technological Advancements in Spray Technology

Three new concepts have come to fruition in pesticide application technology in recent years:

1. use of drones, referred to as Unmanned Aerial Systems (UAS), for a variety of tasks, including orchard and vineyard spraying
2. variable-rate application of pesticides
3. site-specific application of pesticides

Below is a brief description of these concepts. More information on this topic is available in the Ohio State University Extension publication (FABE-538) “Advancements in Technology for Effective Spraying in Orchards and Vineyards” (ohioline.osu.edu/factsheet/fabe-538).

Use of Drones for Spraying

Although not common in the U.S., aerial application of pesticides using drones, as shown in Figure 11, is becoming routine in other parts of the world. This is especially true in small-acreage, Southeast Asian and European vineyards, and orchards where the topography does not allow spraying by conventional fixed-wing aircraft, as shown in Figure 12.

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 that disperse the pesticides. Their spray tank capacity ranges between two to five gallons, and their application rate usually runs between one to two gallons per acre. Depending on the application rate, the spray mixture in the tank may last four to 10 minutes.



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Figure 11. Drones are successfully used in vineyards and orchards for different purposes, including spraying pesticides.



Photo by Flavio Vallenari, iStock

Figure 12. Drones are gaining popularity in areas where using conventional spraying equipment is neither safe nor practical.

The maximum flying speed of drones is 15 to 20 miles per hour. Batteries last five to 15 minutes, depending on the battery size and type. Some drones can also be programmed to fly to their home base to refill their tank when it's empty. Once replenished, 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 when spraying is done over uneven terrains. Using this feature, the drone can automatically navigate hills and slopes.

Currently, several factors, including Federal Aviation Administration (FAA) restrictions, are contributing to the slow adaptation of drone spraying by fruit growers. However, these limiting factors are likely to be relaxed and remedied in the future considering the significant interest in and popularity of the idea of drone 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, creating gaps between grapevines as shown in Figure 13.

In addition, the canopy size in the same vineyard or orchard significantly varies as the growing season progresses, and this growth rate may be different in vineyards or orchards depending on many things including soil characteristics and the topography. Unfortunately, today's conventional sprayers don't 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,



Javier Campos, Polytechnic University of Catalonia, Spain

Figure 13. Gaps between grapevines should not be sprayed.

especially during spraying done early in the season when there is very little canopy cover. 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 for a variable-rate application of pesticides in orchards, vineyards, and nurseries (Chen et al. 2012 and Shen et al. 2017). This unique spraying system, shown in Figure 15, integrates a high-speed, laser-scanning sensor to a custom-designed, sensor-signal analyzer and variable-rate controller to manipulate the duration of the variable-rate pulse width modulation (PWM) nozzles in a multi-channel delivery system. It detects canopy presence; measures canopy size, shape, and foliage density; and then independently controls the spray output of individual nozzles to match canopy volume and travel



Dr. Heping Zhu, USDA-ARS

Figure 14. Intelligent variable-rate sprayer developed in Ohio.

speed in real time. Field tests demonstrated that this sprayer technology could reduce airborne spray drift by up to 87%, reduce spray loss onto the ground from 68–93%, and lower spray volume from 47–73% while maintaining effective control of insects and diseases.

Currently, the company Smart Guided Systems has commercialized this technology in the U.S. Smart Guided Systems 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.

Site-Specific Application of Pesticides

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. Therefore, it may be necessary to spray different types of pesticides at different rates, depending on what part of the orchard or vineyard is being treated.

Technologies now exist and are being developed for site-specific applications of pesticides. This is a two-step process. First, a drone flies over the field and gathers data—usually through cameras—to identify ground conditions, such as canopy characteristics, areas that exhibit nutrient stress levels, or areas infested by insects and diseases that may require pesticide spraying. The photos taken by the cameras are later digitized and a map of the parameters mentioned above is generated. This data is then used to perform site-specific spraying using a drone equipped with spraying components or using a tractor-driven sprayer outfitted with GPS technology. When the drone or conventional sprayer comes to an area identified as needing spraying by the digitized map, the nozzles are activated. Spraying stops in the no-spray zones identified on the digitized map. This process continues until the entire field is sprayed as prescribed by the digitized map.

Detailed information on recent advancements in technology for effective spraying in orchards and vineyards is provided in the Ohio State University Extension publication (FABE-538) “Advancements in Technology for Effective Spraying in Orchards and Vineyards” (ohioline.osu.edu/factsheet/fabe-538).

Effective Spraying and Sprayer-Calibration Software

There are several well-designed and credible web-based software programs that 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 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 free of charge at dosavina.upc.edu and 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. in the reference section.

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 to be controlled, the product to be applied, and the type of spraying equipment used. It shows how dose rates can be lowered when using more efficient new generation of sprayers such as tangential flux sprayers in fruit orchards, and vertical booms or recycling sprayers in vineyards. This resource is available at dosa3d.cat/en and on Android-based smart phones. Work is in progress to make it available in iOS format. Detailed information about **Dosa3D**[®] is available in a 2022 journal article by Román et al. listed in the reference section.

Summary and Recommendations

Technology is advancing to help grape and fruit tree growers apply pesticides more effectively and efficiently. However, we still need to pay attention to the conventional, common-sense, and practical aspects of spraying when applying pesticides in vineyards and orchards. 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 field crops that are a short distance below a sprayer boom 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 rather difficult. Here is a summary of some of the topics discussed in this publication and some final recommendations:

- Carefully read and follow the recommendations provided on the pesticide label, in the nozzle manufacturers' catalogs, and in the sprayer operator's manuals.
- 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.
- Select the right type and size of nozzle to achieve maximum pesticide deposit and coverage on the target.
- Calibrate the sprayer to ensure the recommended amount of pesticide based on the product's label is applied.
- Understand how to calculate the correct amount of chemical product to mix in the tank.
- Check the sprayer setup to ensure that the pesticide is distributed evenly on all parts of the canopy.
- 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.
- Operate the nozzles at a pressure that allows them to produce the spray quality (droplet size) recommended on the product label.
- Keep spray drift in mind. Take precautions to reduce it to minimum. Consider using drift-reduction nozzles.
- 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.
- Take advantage of technological advancements in spray technology, such as variable-rate and site-specific application that reduces pesticide consumption.
- Utilize apps developed by sprayer/nozzle manufacturers to select the best nozzle type and size for a specific application situation.
- 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.

- Conduct tasks such as sprayer calibration and mixing and loading of chemicals in areas that do not have ground and/or surface water pollution.
- 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.

The following websites are excellent sources of additional information on spraying orchards and vineyards:

- platform.innoseta.eu
- sprayers101.com/airblast101

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