

Calibration of Orchard and Vineyard Sprayers

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A sprayer can only be effective, efficient, and safe if it's properly checked and calibrated before it's 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, 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.

How Should the Application Rate Be Expressed?

Usually, the spray application rates on product labels are given in “gallons per acre” for both field crops using boom-type sprayers and for orchard or vineyard spray applications. For field crop spraying, the “acre” refers to the “field acre” which is the same as the “treated acre” because the target being sprayed is usually uniformly distributed across an acre of ground.

On the contrary, the target in orchards and vineyards is three dimensional (length, height, width, and depth) with great variations in size. The targets being sprayed are rows separated by a distance of 8–12 feet. So, only a portion of the field acre is treated in the case of orchards or vineyards. Even in the same orchard or vineyard, the canopy volume may show significant variation during the growing season with significant gaps between trees or vines.

Therefore, the “gallons per acre” application rate on a product's label may be appropriate for field crops, but not completely accurate for orchard and



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vineyard spraying. A better approach is for pesticide manufacturers to provide recommendations based on adequate coverage of the canopy, rather than the acres being sprayed. In recent years, this realization has sparked considerable discussion among researchers and companies producing pesticides for orchards and vineyards regarding the use of a description other than “gallons per acre” to express the required spray application rate for orchards and vineyards. Concepts such as Tree Row Volume (TRV) for orchards, and Leaf Wall Area (LWA) for vineyards are gaining acceptance in Europe, resulting in their chemical companies changing the application rate to TRV or LWA on their labels. Unfortunately, there is very little movement in the U.S. among manufacturers and users of pesticides regarding changes in the way dose rates are expressed.

As a result, although not very accurate, growers applying pesticides in orchards and vineyards will continue to calibrate their sprayers to satisfy the required rates given on the product labels in gallons sprayed per acre. Therefore, the main objective of the calibration method explained in this publication is to determine the actual application rate of a sprayer in gallons per acre, and make the appropriate changes if the difference between the actual and the intended rates is greater than 5% of the intended rate.



Things to Do Prior to Calibration

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. Some nozzles or screens may become clogged causing under-application. Clean all clogged nozzles and screens before calibrating the sprayer and after each application (especially when powder sulfur or copper are applied in vineyards). Observe the spray pattern before calibration, and often during spraying to make sure there is no clogging.

Nozzle wear from extended use causes over-application and/or non-uniform application. Check the flow rate of each nozzle for at least 30 seconds and then replace the old nozzles with new nozzles and compare the new nozzle flow rate with the flow rate of 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.

Checking the flow rate of nozzles is a relatively safe process when working with field sprayers that have nozzles affixed to a horizontal boom. These nozzles discharge spray toward the ground. It is easy and safe to hold a cup under the nozzle and measure the flow rate without getting wet. With orchard sprayers, the discharge is horizontal or slightly upward which makes collecting spray from the nozzles rather challenging. To avoid getting wet, the best approach is to securely attach hoses to each nozzle and collect the nozzle output as shown in Figures 1 and 2. There are clamps specifically designed to attach hoses to the nozzles (Figure 3). The much cheaper option is to use milking liners as shown in Figure 2.



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Figure 1. Hoses should be connected to each nozzle to determine the flow rate.



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Figure 2. Using milking liners to connect nozzles to the hoses is a practical and economical way to check flow rates of nozzles.



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Figure 3. Clamps specifically designed to attach hoses to the nozzles.

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

Three things are needed to take sprayer-calibration measurements:

1. A timer or smart phone showing time in seconds
2. A measuring tape
3. A measuring cup graduated in ounces

Calibrating the Sprayer

Calibrating an airblast sprayer used in an orchard or vineyard involves the following steps:

1. Fill the sprayer tank with water to at least half of the tank's capacity.
2. Measure the row spacing—the distance between two rows in the orchard or vineyard—in feet.
3. Measure a distance in the field, preferably longer than 200 feet.
4. Drive through the measured distance in the field at normal spraying speed and record the travel time in seconds. Repeat this procedure and average the two measurements
5. Calculate the travel speed (miles per hour) as follows:

$$\text{Travel speed (MPH)} = \frac{\text{Distance (feet)}}{\text{Travel (seconds)}} \times 0.68$$

For example, if the travel distance was 200 feet, and it took an average of 40 seconds to travel this distance, the sprayer travel speed is 3.4 mph. The constant 0.68 is used to convert feet per second to miles per hour.

$$\frac{200 \text{ feet}}{40 \text{ seconds}} \times 0.68 = 3.4 \text{ mph}$$

6. Park the sprayer and run it at the pressure and revolutions per minute (RPM) setting you will use in the orchard or vineyard while catching the output from each nozzle in a measuring jar for a set time period (preferably 1 minute, or at least 30 seconds).
7. Convert the output in ounces collected from each nozzle to ounces-collected-per-minute. For example, if you collected 20 ounces in 30 seconds, the ounces-collected-per-minute is 40.
8. Convert ounces-per-minute to gallons-per-minute. (Remember, there are 128 ounces per gallon). For example, if the ounces collected per minute is 40, then gallons-per-minute is 0.3 gal. per minute (40 divided by 128 = 0.3).
9. Add the gallons-per-minute output from each nozzle together and then divide the total by the number of nozzles tested. This determines the actual gallons-per-minute (GPM) flow rate from all the nozzles on both sides of the sprayer.

10. Calculate the expected (required, or intended) nozzle output (GPM). Base the calculation on the application rate on the chemical label, or the desired rate of application (GPA), the calculated travel speed (mph), and the row spacing (ft) using the following equation:

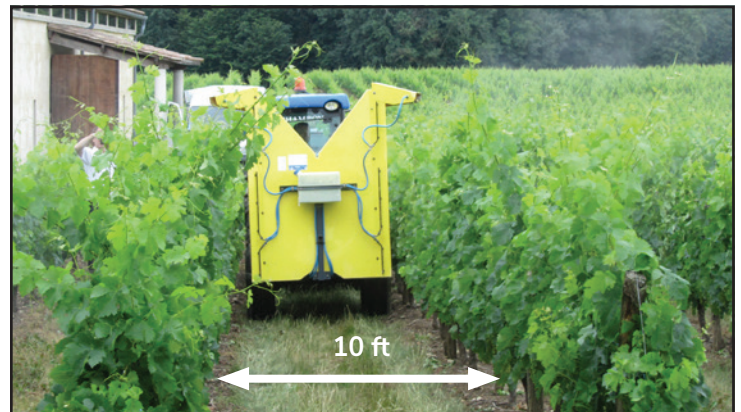
$$\text{Output both sides (GPM)} = \frac{\text{Application Rate (GPA)} \times \text{MPH} \times \text{Row spacing (ft)}}{495}$$

The constant 495 is used to convert GPA, MPH, and feet on the right side of the equation to GPM.

11. Compare the actual gal/min nozzle flow rate (resulting from flow rate measurements detailed in Step 10 above) with the intended nozzle flow rate (GPM). Determine the percent error using the following formula:

$$\text{Percent error} = \frac{\text{Actual flow rate} - \text{Expected flow rate}}{\text{Expected flow rate} \times 100}$$

12. If the difference between the actual and the intended application rate is greater than 5% of the intended rate, adjustments to the sprayer must be made to bring the error margin below 5%. Adjustments include changing the spray pressure, changing the travel speed, or changing both. If these changes are impractical (i.e., travel speed changes may result in dangerous sprayer operation, or pressure changes may result in significant changes in the droplet size), the third option is to replace the nozzles with a larger or smaller size of the same nozzle type. For information on nozzle selection, please read the 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).



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Figure 4. Sprayer applying pesticide to grapevines.

EXAMPLE

What We Know:

Intended spray application rate: 200 gallons per acre (GPA)

Travel speed: 5.0 mph

Row spacing: 10 feet

Actual total nozzle flow rate (from measurements): 18 gallons per minute (GPM)

What We Want To Know:

What is the total expected (intended, or desired) nozzle flow rate (GPM)?

Is the error between the actual and the expected nozzle flow rate acceptable (less than 5%)?

First, calculate the expected nozzle flow rate:

$$\frac{200 \text{ (gallons per acre)} \times 5 \text{ (mph)} \times 10 \text{ ft.}}{495} = \frac{200 \text{ gallons}}{\text{per minute}} \text{ (total desired nozzle output)}$$

Next determine the percent error between the actual and the expected flow rate:

$$\text{Percent error} = \frac{\text{Actual flow rate} - \text{Expected flow rate}}{\text{Expected flow rate}} \times 100$$

$$\text{Percent error} = \frac{(18 - 20)}{20 \times 100} = -10\% \text{ (under application)}$$

Since the application error of 10% is greater than the recommended maximum error margin of 5%, adjustments must be made in either the spray pressure (increasing the pressure in this case), the travel speed (reducing the speed in this case), or, if necessary, a combination of both. If changes in either or both the pressure and the travel speed cannot be made for reasons such as extreme changes in droplet size, or unsafe driving speed, new nozzles with the appropriate size should be put on the sprayer.

The procedure outlined above may need to be repeated with new measurements taken each time an adjustment is made in order to reach an application error within the 5% limit. However, a much easier way is to use the following equations to determine the new pressure or travel speed needed to bring the application error to zero.

To determine the appropriate travel speed (MPH) for a desired application rate, or gallons per minute (GPM):

$$\text{MPH}_2 = \frac{(\text{GPM}_1 \times \text{MPH}_2)}{\text{GPM}_2}$$

To determine the appropriate pressure (PSI) for a desired application rate (GPM):

$$\text{PSI}_2 = \text{PSI}_1 \left(\frac{\text{GPM}_2}{\text{GPM}_1} \right)$$

Definitions of Acronyms:

GPM₂, GPM₁: Desired and measured application rate, respectively (gallons per minute).

MPH₂, MPH₁: Desired and measured travel speed, respectively (miles per hour).

PSI₂, PSI₁: Desired and measured spraying pressures, respectively (lbs. per square inch)

Important Items to Remember About Calibration of Sprayers

1. For safety reasons, calibration should be done using water in the sprayer tank. A mixture containing pesticides may have a slightly higher density or viscosity than water, which may slightly reduce the flow rates of nozzles. Usually, the difference in flow rates between water alone and a mixture containing pesticides is not significant unless a high volume of high-dense or viscous adjuvant are included in the spray mixture. Conversions for spray solutions with different densities are provided by the nozzle manufacturers in their catalogs or websites.
2. Even when calibrating the sprayer using water, always wear the personal protective equipment used for spraying pesticides, such as gloves and goggles.
3. This fact sheet covers topics related to canopy spraying, mostly by using air-assisted sprayers. For more information on the calibration of boom type of sprayers for the treatment of weeds, please read the Ohio State University Extension publication FABE-520, "Calibrating Boom Sprayers," (ohioline.osu.edu/factsheet/fabe-520).

Other Adjustments Needed for Effective Spraying

Adequate amounts of pesticide (gal/acre determined through calibration) discharged from the nozzles is important, but this is only one aspect of achieving effective pest control. How much of the spray reaches the target canopy, and how uniformly it is distributed within the target canopy are two other factors that play important roles in achieving maximum protection against pests.

How to Efficiently and Effectively Deliver Spray from the Nozzle to the Target

The goal in spraying fungicides and insecticides should be landing as many droplets on the target as possible. Reducing the off-target movement of droplets starts with the sprayer. The most common type of sprayer used in orchards and vineyards in the U.S. is the air-assisted (airblast) sprayer shown in Figure 5. Unfortunately, this sprayer has two design and/or adjustment issues that significantly reduce the spray deposited on the target:

1. The top two to three nozzles on each side of the sprayer aren't directing spray toward the targets and should be turned off.



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Figure 5. This type of airblast sprayer is most commonly used in orchards and vineyards. Note that the sprayer lacks deflector plates, and that the top three nozzles should have been turned off to minimize spray waste.

2. There are no deflector plates to direct the air plume towards the target on Figure 5 (these plates are present in Figure 6). These plates ensure that the sprayed droplets are deposited on the canopy.

When spraying an orchard or vineyard, adjust the angle of the deflector plates to match the canopy's height of the canopy. This adjustment is necessary each time spraying is conducted because the canopy height may vary from one orchard or vineyard to another, or even within the same orchard or vineyard throughout the growing season. A practical way to determine the correct trajectory of the air discharged from the fan is to tie ribbons around the area where air is exiting the fan. Then turn on the fan, watch the direction the air blows the ribbons, and adjust the angle of the deflectors accordingly, as shown in Figure 7.



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Figure 6. An airblast sprayer with the deflectors properly adjusted to direct spray to the height of the canopy.



Deveau and Ledebuhr (sprayers101.com/airblast101).

Figure 7. Ribbons tied around the fan show the direction that air is exiting the sprayer.

Sometimes the target may be a certain part of the tree or vine, such as the clusters of grapes on the vine shown in Figure 8. In cases like this, only the nozzles aligned to direct their spray at the clusters of grapes should be turned on. This eliminates wasted spray from nozzles directed toward non-targeted sections of the canopy.



Ernesto Velazquez, Unsplash.

Figure 8. If the target of pesticides are grape clusters, turn on only the nozzles needed to provide spray coverage on this portion of the canopy.

How to Achieve Efficient Penetration and Uniform Deposition of Droplets Inside the Canopy

Air generated by the sprayer fan is what carries droplets from the nozzle to the target. Too little or too much air results in ineffective and inefficient coverage of the target. The goal is to adjust the sprayer fan air-flow rate and volume so that 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. This adjustment will result in very little spray droplets escaping the canopy. Be aware that too much air flow can force leaves together, creating a surface that blocks the passage of air. When air cannot penetrate the canopy, it moves upward in a vertical trajectory, further exacerbating the off-target movement of droplets. In general, most, if not all of today's air-assisted or airblast sprayers, generate more air assistance than what is needed. This is especially true for vineyard spraying. So, it is very important to take the time to adjust the air stream characteristics (direction, air speed, and air flow rate) suitable for the tree or vine canopy conditions at the time of the spray applications. As a side benefit, a reduction in the airflow rate also lowers fuel consumption.

To determine if there is optimum air flow through the canopy, tie ribbons on the outer sides of the

canopy rows being sprayed. Then turn on the fan and watch the ribbons. They should display very little movement. If needed, adjust the airflow rate to achieve the optimum air flow. Some new sprayers allow the operator to adjust the opening in the fan's air intake section to best match canopy conditions. For sprayers that don't have this feature, but are powered by a hydraulic motor, adjust the fan speed. If the fan is not powered by a hydraulic motor, try the following options:

- Run the engine at lower speeds to reduce the Power Take-Off (PTO) shaft speed (this may not be practical on hilly grounds).
- Adjust the angle of the fan blades.
- Partially cover the fan's air intake section to reduce the volume of air going into the fan.

The most practical and easy way to determine the location and uniformity of pesticide applications is to use water-sensitive papers attached to leaves in different locations (depth and height) of the canopy. These water-sensitive papers should also be affixed to the upperside and underside of leaves. Check the coverage on these cards after spraying pesticides.

Spray droplets landing on 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 canopy. The coverage shown on the card in Figure 9 is ideal for most situations, with approximately 30% of the card covered with spray droplet stains.



Emilio Gil, Polytechnic University of Catalonia.

Figure 9. A water sensitive card after the spraying is finished. This pattern on the card represents ideal coverage for the target being sprayed.

Summary and Recommendations

Careful selection of the best sprayer type and the best type and size of nozzles is a good starting point to achieve satisfactory results from spraying pesticides in orchards and vineyards. Although the air-assisted sprayers shown in Figures 5 and 6 are the types used by most tree fruit and grape growers in the U.S., many other more efficient types of air-assisted sprayers are used in other parts of the world. Check the 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) to see other types of sprayers used in orchards and vineyards. Be aware, however, that all sprayers, whether they are brand new or used, should be properly checked and calibrated before they are taken to the field. They should also be periodically checked during the spraying season to ensure an effective, efficient, and safe application of pesticides.

Following the calibration process, necessary adjustments in sprayer operating conditions must be made if the difference between the actual rate (determined as a result of calibration) and the intended rate is greater or less than 5% of the intended rate. Adjustments to bring the error margin below 5% may include changing the spray pressure, changing the travel speed, or changing both. If further changes in pressure and travel speed cannot be made, then the best option is to replace the nozzles with a larger or smaller size of the same nozzle type. Other adjustments include changing the direction and/or rate of air flow while calibrating the sprayer.

Using the most appropriate sprayer and calibrating the sprayer for

the vineyard or orchard being sprayed are very important steps in achieving satisfactory results from pesticide application.

However, there are several other tasks that need to be completed to achieve the best results when spraying pesticides in orchards and vineyards:

- Carefully read and follow the recommendations provided on the pesticide label, in the nozzle manufacturers’ catalogs, and in the sprayer operator’s manuals.
- Operate the equipment properly to achieve the maximum deposition of pesticides on all parts of the canopy—not just the outer sections of the canopy—while providing optimum coverage on the target and minimum loss of pesticides in the air and on the ground.
- 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.
- Operate the nozzles at a pressure that allow them to produce the spray quality (droplet size) recommended on the product’s label.
- Use apps for smart phones developed by sprayer/nozzle manufacturers to select the best nozzle type and size for each specific application situation.
- Understand how to calculate the correct amount of chemical product to mix in the tank.
- 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.
- Take advantage of technological advancements in spray

technology, such as variable-rate and site-specific application, that reduces pesticide consumption.

- 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.

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