HS1220

Calibration of Chemical Applicators Used in Vegetables[1]

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Introduction

Calibration is the process used to determine the amount of chemical material applied per unit area. This unit is typically an acre in most agricultural operations. Equipment for applying liquid and dry materials must be accurately calibrated for pesticides to work efficiently and to avoid crop injury or death. The pesticide label is a legal document and must be followed. Properly calibrating equipment ensures the product is being applied as specified on the label and that environmental contamination will be minimized. This publication discusses some methods for calibration of sprayers and dry material spreaders and includes information about calibration to help growers properly apply pesticides.

Figure 1. An applicator cleans out the boom of a self-propelled sprayer.
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Definition of Terms

GPA: Gallons per acre applied by the sprayer

GPM: Gallons per minute delivered by the sprayer nozzles

MPH: Miles per hour the spray equipment is traveling

Swath: Width of material applied by the application equipment

Selecting Nozzles

When selecting nozzles for chemical application, a grower should first calculate the correct GPM per nozzle. Once the GPM has been determined, the grower can select the correct nozzle. The goal is to select the nozzle designed for the GPM determined by the calculation. A nozzle consists of a nozzle body, a strainer (screen), a core (whirl-plate), a disc (orifice), and a nozzle cap (Figure 2).

Nozzle Spray Patterns

1. **Flat fan** – This type is designed to operate on a boom and is the most commonly used nozzle tip. Flat fan nozzles are designed to operate properly with approximately one-third overlap with adjacent nozzles for an even distribution of spray across the target site. The spray pattern on flat fan nozzles decreases to ½x on the edges of the pattern so overlapping keeps a uniform 1x pattern across the target site.

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Figure 2. A nozzle includes the nozzle body, strainer, core, disc, and nozzle cap.
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2. **Even fan** – This type is designed to operate for spot treatments using a single nozzle boom. Even fan nozzles produce an even distribution of spray across the entire spray width.

3. **Cone** – This type is commonly used to apply fungicides and insecticides because they operate at high pressures to penetrate the crop canopy. These nozzles are designed to be accurate and apply a high volume of small droplets.

Nozzle Numbers

The first two to three numbers found on a nozzle tip are the nozzle's spray angle. For example, a 11004 nozzle will have a 110° spray angle.

The last two numbers are the flow rate. For example, a 11004 nozzle will have a 0.4 GPM flow rate at 40 PSI (pounds per square inch).

Nozzle Color

Some spray nozzles are categorized by color. Table 1 shows the color by GPM at 40 PSI.

Spray Screens

Nozzle screens are designed to keep debris from clogging the nozzle tip. The two screens typically used are 50 and 100 mesh screens. Any nozzle 0.2 GPM or smaller (i.e., 0.15 and 0.1 GPM) requires a 100 mesh screen. Any nozzle larger than 0.2 GPM requires a 50 mesh screen. Screen numbers (50 or 100) indicate the number of openings per inch. Smaller screens (100 mesh) are used for 0.2 GPM nozzles and lower because if a 50 mesh screen was used, the holes in the screen would be larger than the nozzle orifice.

How to Determine GPM

Pesticide labels often list a recommended speed for application. Speed is one of the variables needed to determine GPM using the 5,940 conversion factor. Nozzle spacing in inches and GPA are also variables in the 5940 formula for GPM, which is as follows:

$$\text{GPM} = \frac{(\textit{nozzle spacing in inches x mph x GPA})}{5940}$$

If you do not know GPA, but do know GPM, you can use the following equation:

$$\text{GPA} = \frac{(5940\ \textit{x GPM})}{(\textit{nozzle spacing in inches x mph})}$$

Using the formulas above, you can calculate for any variable listed by back-calculating and solving for the missing variable. Back-calculating is a helpful way of finding missing variables in the GPM or GPA formulas.

Alternative Methods to Determine GPM

Three alternative methods to determine the GPM delivered by a sprayer are 1) the nozzle flow test method, 2) use of volume graduations, and 3) the tank refill method.

Nozzle Flow Test

The nozzle flow test is the preferred method for determining GPM. Before adding pesticides to the tank, fill the tank with plain water for calibration. Turn on the nozzle, and collect water from each nozzle in a graduated cylinder for a period of 15 seconds. Multiply the amount collected from individual nozzle flows by four (Figure 3).

Table 1.

Orange: 0.1 GPM	Green: 0.15 GPM	Yellow: 0.2 GPM	Purple: 0.25 GPM	Blue: 0.3 GPM	Red: 0.4 GPM	Brown: 0.5 GPM	Grey: 0.6 GPM	White: 0.8 GPM

Figure 3. An applicator performs the nozzle flow test.
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Using Volume Graduations

If the sprayer tank has visible volume graduations, GPM can be determined by running the sprayer until the level drops from one graduation to another and dividing by the time it takes for the level to drop. Use of tank graduations eliminates the need to restore the initial level with a measured amount of liquid. Before using this method, the tank graduations should be checked for accuracy by pouring a known volume of liquid into the empty tank and comparing the known volume to the amount indicated by the graduations. If the tank level is significantly different from the known volume, then the tank should be marked with new graduations.

$$\text{GPM} = \frac{\textit{Gallons}}{\textit{Time (in minutes)}}$$

Tank Refill Method

Fill the sprayer to a well-marked, easy to repeat level, and then run the sprayer for a measured period of time. Measure the amount of liquid needed to restore to the original level in the tank. Divide the gallons replaced by the time in minutes.

$$\text{GPM} = \frac{\textit{Gallons}}{\textit{Time (in minutes)}}$$

Nozzle Selection Example

A grower wants to use a flat fan nozzle sprayer to apply 40 gallons per acre of pesticide. The sprayer will travel at 3 MPH, and the width between the nozzles is 12 inches. The grower wants to apply the spray using 40 PSI. What nozzle should the grower use? (Use Table 2 to solve the question.)

Table 2 gives the GPM delivered by a series of flat fan nozzles at various pressures.

$$\text{GPM} = \frac{\textit{GPA x MPH x nozzle spacing in inches}}{5940}$$

$$\text{GPM} = \frac{(40 \times 3 \times 12)}{5940}$$

$$\text{GPM} = 0.24$$

In this example, a nozzle that delivers approximately 0.24 GPM at 40 PSI must be chosen. Looking at the "Capacity one nozzle in GPM" column, the GPM of 0.24 can be reached with the 11002 nozzle tip. However, the PSI required for this tip is 60. The grower wants to use 40 PSI. Continuing down the "Capacity one nozzle in GPM" column, the 110025 nozzle tip will apply a GPM of 0.25 and a PSI of 40. This would be the correct nozzle in this example.

Table 2.

Nozzle Number	PSI	Capacity one nozzle in GPM
11002	15	0.12
	20	0.14
	30	0.17
	40	0.20
	50	0.22
	60	0.24
110025	15	0.15
	20	0.18
	30	0.22
	40	0.25
	50	0.28
	60	0.31
11003	15	0.18
	20	0.21
	30	0.26
	40	0.30
	50	0.34
	60	0.37
11004	15	0.24
	20	0.28
	30	0.35
	40	0.40
	50	0.45
	60	0.49

Determining the Acres Treated by a Volume of Spray

The number of acres treated by a sprayer depends on the volume of spray solution in the tank and the GPA. Applications will either be a broadcast application in which a large area of the field is treated or a strip (banded) application.

To determine a broadcast application use the following equation:

Treated Area = length x width of field

To determine a strip or banded application use one of the following equations:

Treated Area = Bed top width x row length x number of rows x 43560 ft^2

$$\text{Treated Area} = \frac{\textit{Treated strip width}}{\textit{between row spacing}} \text{ x total acres of field}$$

Always Run a Field Calibration Test

A field calibration must be conducted to determine the actual GPA applied by the sprayer. Nozzle manufacturers' performance charts used to select nozzles give flow rates for new nozzles. The pressure is assumed to be at the nozzle, and the liquid carrier is assumed to be water. In contrast, the following may be true when calibrating a sprayer:

1. **Worn nozzles may deliver more than the chart values.** It is recommended that nozzles be replaced when the flow exceeds 10% more than the flow delivered by a new nozzle. This is because the droplet spectrum and overall resulting coverage will be adversely affected.

2. **The spray gauges may be incorrect.** The spray pressure gauge may be inaccurate, or may be located at a point on the sprayer where the pressure is much different from the pressure at the nozzles.

3. **The spray solution flow characteristics could be significantly different from water.**

4. **Nozzles may be clogged with debris.**

How Can You Change Application Rates?

Assume that the field calibration test of the sprayer in the following example shows that the sprayer applies 44 GPA rather than the desired 50 GPA. A grower could choose one of the three alternatives listed below:

1. Adjust pressure. Change the pressure to increase the flow enough to apply 50 GPA. This is a reasonable choice in this case because the difference between the desired (50) and the measured (44) is small. If the difference is large, it is not feasible to achieve the desired GPA by changing pressure. The flow rate varies as the square root of pressure changes. Large changes in pressure cause relatively small flow changes. The pressure has to be increased four times to double the flow.

The formula to adjust pressure and/or find GPM is the following:

$$\frac{GPM1}{GPM2} = \frac{\sqrt{PSI\ 1}}{\sqrt{PSI\ 2}}$$

2. Adjust speed. Change the speed to make the sprayer apply the desired GPA rate. The GPA rate varies indirectly with the field speed of the sprayer. Doubling the speed will half the GPA applied, and halving the speed will double the GPA (assuming the nozzle flow remains constant). Changing speed is a good way to change the application rate. However, there is a practical limit to the change that can be accomplished by changing speed. Going very slow requires more time to complete the job, and going too fast for the field conditions can be dangerous. (Figure 4 contains the monitor inside a self-propelled sprayer. Here you can see how the applicator can monitor and adjust the pressure and speed.)

Figure 4. An applicator can use the monitor inside a self-propelled sprayer to adjust pressure and speed.
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3. Consult the label. Apply the GPA that was determined during the calibration test. GPA is not typically a rigid number, and pesticide labels give a range. For example, if a grower calibrated a sprayer to apply at 50 GPA and a field calibration test showed it was actually applying 44 GPA, the sprayer is determined to be reasonable (within approximately 20%–25% of the targeted amount). In the example, the label does not forbid the GPA to be used as is, but the quantity of pesticide will need to be adjusted.

What Pressure Should Be Used?

The pressure used to apply pesticides depends on the pest problem. Low pressure (15–40 PSI) is generally used for applying herbicides, medium pressure (80–100 PSI) for applying insecticides, and high pressure (100–400 PSI) for applying fungicides.

Low pressure is generally used for applying herbicides with fan nozzles. The angle made by the edges of the nozzle fan depends on the nozzle design and the pressure. The most common fan angles are 80° and 110°. Every nozzle has a set maximum and minimum PSI that should be used. A pressure that is too high will result in smaller, mist-like droplets. A pressure that is too low will result in larger droplets.

Insecticides are applied at higher pressures than herbicides because the nozzles produce more droplets, resulting in better plant coverage. Producing small droplets increases the potential for drift. However, the residue levels in neighboring areas that cause a noticeable problem are usually higher for insecticides than for herbicides.

Fungicides are sometimes applied at extremely high pressures (400 psi range). This high pressure is used to improve coverage by producing a large amount of small droplets. Using high pressure can improve penetration and coverage. However, the risk of drift is much higher.

Calibrating Dry Material Applicators

The process used for calibrating dry material applicators is very similar to the method described for liquid sprayers. The basic equation used is the following:

$$\text{PPA} = \frac{\boldsymbol{PPM}}{(\boldsymbol{ac/\,min})}$$

In the equation:

PPA = pounds applied per acre

PPM = pounds applied per minute

ac/min = acres per minute

The equation above can be used for any type of dry material application equipment. Dry material applicators often have manuals that give approximate settings of the opening in the hopper bottom. These settings should be used only as a starting point for the calibration process. Generally, dry material applicators cannot be calibrated as accurately as liquid sprayers because of the flow properties.

Determining Acres Treated Per Minute

The equation used to determine the acres treated per minute by a dry material applicator is the same as the one used for determining the acres treated per minute for a liquid sprayer (1 MPH = 88 fpm):

$$\text{Acres per Minute} = \frac{\boldsymbol{swath\ (ft)\ x\ speed\ (fpm)}}{\mathbf{43560}}$$

The application of dry material pesticides is typically only used in ornamental crops and municipal settings. The application of dry pesticide formulations in crops is uncommon.

Sprayer Calibration Worksheet

Step 1	Determine your GPM using the 5940 formula. Once you have determined your GPM, convert gallons into mL by multiplying by 3785.
Step 2	Fill the spray tank with clean water and place a 1000-mL graduated cylinder under each spray nozzle.
Step 3	Run the sprayer for 15 seconds, collecting the water in the graduated cylinders.
Step 4	Measure the amount of water collected in each graduated cylinder. Add up the total amount of water collected in all of the graduated cylinders. Multiply by four, and divide by the total number of nozzles. Finally, divide that number by four.
Step 5	Now that you have determined the output of your sprayer, compare the GPM of the sprayer to the GPM you calculated in Step 1. (The correct range for your sprayer output should be within +10% or –10% of the calculated output.)