

# CHAPTER 4

## CALIBRATION

### LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand the purpose of calibration and why it is an essential process.
- Know the basic tools needed to calibrate sprayers and the variables that determine spray rate.
- Be able to check for and calculate nozzle output and know the guideline for determining when nozzles are worn out.
- Know what factors affect spray pattern uniformity and how to check for it.
- Understand how to calibrate a sprayer for *broadcast application*.
- Be able to calculate how much pesticide to add to the spray tank for broadcast application.
- Know how to properly calibrate a hand sprayer on a per-acre basis and for a *band application*.
- Know how to calibrate granular applicators, both drop-through spreaders and rotary spreaders.

### INTRODUCTION

The purpose of **calibration** is to ensure that your equipment delivers the correct amount of pesticide uniformly over the target area. Calibration is the step in pesticide application that is most often neglected and misunderstood. Because virtually every sprayer is a unique combination of pumps, nozzles, and other equipment, calibration is an essential process for an applicator to learn.

For proper calibration, you will need a few basic tools, including a stopwatch, a collection container graduated in ounces, a tape measure, and flags or stakes for marking.

Unless your sprayer is new, it will contain a certain amount of pesticide residue; therefore, a pair of chemical-proof gloves is also recommended. Additionally, a pocket calculator will help with calculations.

In this chapter, we provide formulas that are designed to make calibration easier for you. Some of these formulas have constants – i.e., numbers that remain the same whenever you use that formula. To make calibrations easier for you, we provide you with the constants.

### CALIBRATION OF SPRAYERS

Calibrating a sprayer ensures that the sprayer is delivering the intended volume of spray mixture to the target area. You must determine each of the following:

- The amount of product the sprayer delivers per acre.
- The number of acres you can spray per tank.
- The recommended rate of pesticide application.
- The amount of pesticide to add to the spray tank.

### Variables that Determine the Spray Rate

Two major variables affect the amount of spray mixture applied per acre (most commonly expressed in gallons per acre): the *nozzle flow rate* and the *ground speed* of the sprayer. You must understand the effect that each of these variables has on sprayer output to calibrate and operate your sprayer properly.

#### Nozzle Flow Rate

The flow rate through a nozzle varies with the nozzle pressure and the size of the nozzle tip. Increasing the pressure or using a nozzle tip with a larger opening will increase the flow rate (gallons per acre).

Increasing pressure will NOT give you a proportional increase in flow rate. For example, doubling the pressure

will not double the flow rate – you must increase the pressure fourfold to double the flow rate.

Sprayer pressure (speed constant)	Sprayer output (gallons per acre)
10 psi	10
40 psi	20
160 psi	40

Pressure cannot be used to make major changes in spray rate, but it can be used to make minor changes. Keep in mind that operating pressure must be maintained within the recommended range for each nozzle type to obtain a uniform spray pattern and minimize drift.

The easiest and most effective way to make a large change in flow rate is to change the size of the nozzle tips. Depending on operating pressure, the speed of the sprayer, and nozzle spacing, small changes in nozzle size can significantly change sprayer output per acre. Use nozzle manufacturers' catalogs to select the proper tip size.

### Ground Speed of the Sprayer

Provided the same throttle setting is used, as speed increases, the amount of spray applied per unit area decreases at an equivalent rate. For example, doubling the ground speed of a sprayer will reduce the amount of spray applied by one-half.

Sprayer speed (under constant pressure)	Sprayer output (gallons per acre)
1 mph	40
2 mph	20
3 mph	13.3
4 mph	10

To determine the new output after changing speed:

$$\text{New output} = \frac{\text{old output} \times \text{old speed}}{\text{new speed}}$$

Some low-pressure sprayers are equipped with control systems that maintain a constant application rate over a range of travel speeds, provided the same gear setting is used. Pressure is automatically changed to vary the nozzle flow rate in proportion to changes in ground speed. Even so, do your calibration at a set ground speed. In the field, travel speed must be kept within certain limits to keep the nozzle pressure within the recommended range.

### Precalibration Check of Nozzle Output

After making sure the system is clean, fill the tank approximately half full with water. Fasten a graduated container under each nozzle and operate the sprayer for one minute at a pressure within the recommended pressure range. Check to see that the flow rate from each nozzle is approximately the same; replace or clean any

nozzle whose output differs by more than 5 percent from the average for all of the nozzles and again check the flow rates.

For example, the following flow rates are obtained for six nozzles:

Nozzle	Output (ounces per minute)
1	40.0
2	43.0
3	39.5
4	40.5
5	37.5
6	39.5
Total 240.0 ounces	

The average nozzle output is 40 ounces (240 ÷ 6).

Five percent of 40 ounces (40 × 0.05) is 2 ounces. Any nozzle whose output differs from 40 ounces by more than 2 ounces should be cleaned or replaced; that is, any nozzle whose output is greater than 42 or less than 38. Therefore, nozzle #5 should either be cleaned or replaced. The flow rate of nozzle #2 is too high. This indicates that the nozzle is worn and should be replaced.

When the average nozzle output varies by more than 10 percent from the manufacturer's specifications, the nozzles are worn enough to justify the purchase of a new set. This is particularly important when using flat-fan or flood nozzles because proper spray overlap becomes difficult to maintain with worn nozzles.

### Spray Pattern Uniformity

A uniform spray pattern is crucial for an effective pesticide application. It's not enough to apply a pesticide only in its correct amount – you also must apply it uniformly over the target area. The effects of non-uniform application are most obvious when herbicide bands overlap and streaking results. Spray pattern uniformity is affected by boom height, spacing and alignment of nozzles on the boom, condition of nozzles (worn, damaged), and operating pressure. Check that all nozzles are of the same type. Also, a frequent cause of poor spray patterns is using nozzles with different spray angles on the same boom.

To check the uniformity of the spray pattern, adjust the boom height for the spray angle and nozzle spacing being used. Align flat-fan nozzles at a slight angle to the boom. Using water, operate the sprayer at the desired speed and pressure on clean, dry pavement or on another smooth surface. Observe the spray pattern as the water evaporates. Clean or replace nozzle tips that produce a poor spray pattern; if necessary, readjust boom height and recheck the spray pattern. If you replace any nozzles, recheck the flow rates.

## Broadcast Sprayer Calibration

There are a number of equally effective calibration methods that vary in their basic approach and degree of difficulty. For the purposes of this manual, we have chosen a simple method that will allow you to calibrate quickly.

1. Fill the sprayer tank approximately half full with water.
2. Determine the nozzle spacing or band width in inches and stake out the appropriate distance in the field according to the following table:

Broadcast nozzle spacing or band width (inches)	Travel distance (feet)
8	510
10	408
12	340
14	291
16	255
18	227
20	204
22	185
24	170
26	157

For other nozzle spacings or band widths, determine the appropriate travel distance using the following formula:

$$\text{Travel distance (feet)} = \frac{4,080}{\text{nozzle spacing or band width (inches)}}$$

In this formula, 4,080 is a constant.

For example, if your nozzle spacing is 38 inches:

$$\text{Travel distance} = \frac{4,080}{38} = 107 \text{ feet}$$

*Measuring the appropriate travel distance is a critical step in calibration.* To determine what volume your sprayer is delivering per acre, you must relate the average nozzle output to a smaller unit area of land. You could determine the volume output by physically spraying an entire acre, but this would be very time consuming. Therefore, we use a fraction of an acre.

3. With the sprayer turned off, drive the distance using the exact throttle setting and gear you plan to use during spraying. Be sure to *note the throttle setting and gear*; don't rely on a speedometer. Start the spray rig about 25 feet before the staked area so that you will be at typical field speed at the beginning of the measured distance. *Record your travel time in seconds.*
4. Adjust the pressure to the desired setting. Use slightly higher pressure when you use nozzle check valves and nozzle strainers.
5. With the sprayer stationary, collect and record the output (in ounces) from at least four nozzles for the travel

time recorded in step 3. Because we already determined that the output of all nozzles is within 5 percent of one another in the precalibration check, it is not necessary to collect output from all nozzles.

6. Determine the average nozzle output in ounces.
7. The spray rate in gallons per acre is equal to the average nozzle output in ounces. For example, if the average nozzle output for the recorded travel time is 20 ounces, the spray rate is 20 gallons per acre.
8. If the spray rate is not reasonable for your particular spraying job, you can change output by one of three methods: adjust pressure, change speed, or replace nozzle tips. If only a minor change in output is needed, simply make an adjustment in pressure and determine the new average nozzle output. (Remember that operating pressure must be kept within the recommended range for the nozzle type so the spray pattern is not distorted.) If a large change in output is necessary, make a change in travel speed. However, you must drive the designated field distance and determine the new travel time before calculating the average nozzle output. If it is impossible to obtain the desired output at an appropriate pressure and ground speed, you will need to change nozzle tips; in this case, you must repeat the precalibration check of nozzle output.

The sprayer is now calibrated. When operated at the designated speed and pressure, it should deliver the desired spray volume. You should occasionally remeasure output to determine if changes in flow rate occurred as a result of nozzle wear or other variations. If you continue to use the same travel speed used during initial calibration, it will take only a few minutes to recheck your sprayer's output.

**Example:** You want to make a postemergence broadcast application of a herbicide at a spray volume of 20 to 30 gallons per acre using regular flat-fan nozzles spaced 40 inches apart on the boom:

1. Fill the sprayer tank approximately half full with water.
2. The appropriate travel distance for 40-inch nozzle spacing is 102 feet; measure and mark this distance in the field.
3. Using the throttle setting and gear you plan to use during spraying, you find that it takes 14 seconds to drive 102 feet.
4. Adjust the pressure to the desired setting within the recommended pressure range of 15 to 30 psi for regular flat-fan nozzles; your chosen setting is 25 psi.
5. With the sprayer stationary, you collect the following outputs from four nozzles in 14 seconds:

Nozzle	Output (ounces per 14 seconds)
1	15.5
2	16
3	15.5
4	16
Total = 63 ounces	

6. The average output of the nozzles for 14 seconds is:

$$\frac{63 \text{ ounces}}{4 \text{ nozzles}} = 16 \text{ ounces}$$

7. The spray rate, therefore, is equal to 16 gallons per acre.

8. The spray rate is lower than the recommended range of 20 to 30 gallons per acre stated on the label. The major change in output required should not be attempted by increasing pressure. You'll need to either decrease travel speed (in which case you'll also need to determine the new travel time) or increase nozzle tip size. Then determine the new average output.

## Amount of Pesticide to Add to the Tank

Your next step is to determine the amount of pesticide to add to the spray tank. To do so, you need to know:

- The recommended rate.
- The capacity of the spray tank.
- The calibrated output of the sprayer.

You just learned how to determine the output of your sprayer.

The recommended rate is determined from the label. Rates are expressed either as the amount of pesticide product applied per acre (or area) or as the amount to mix with a certain volume of water (or other carrier).

**Example: Broadcast application.** Pesticide A is recommended as a broadcast application at a rate of 2 quarts per acre. Your sprayer has a 200-gallon tank and is calibrated to apply 20 gallons per acre. How much Pesticide A should you add to the spray tank?

1. Determine the number of acres you can spray with each tank, using the following formula:

$$\text{Acres per tank} = \frac{\text{tank capacity (gallons per tank)}}{\text{Spray rate (gallons per acre)}} = \frac{200}{20} = 10 \text{ acres}$$

2. Determine the amount of pesticide to add to each tank, using the following formula:

$$\text{Amount per tank} = \text{acres per tank} \times \text{rate per acre.}$$

With each tank, you cover 10 acres and you want to apply 2 quarts of product per acre:

$$\text{Amount per tank} = 10 \times 2 = 20 \text{ quarts.}$$

You need to add 20 quarts (5 gallons) of Pesticide A to each tank load.

**Example: Broadcast application.** Pesticide B is an 80 percent wettable powder formulation. After reading the label, you decide to apply 12 pounds per acre for perennial weed control. The area to treat is 150 feet wide and 180 feet long. Your backpack sprayer is equipped with a three-nozzle boom, has a 4-gallon tank, and is calibrated to apply 40 gallons per acre of spray solution. How much water and product do you add to the tank? (43,560 sq ft = 1 acre)

1. Calculate the area to be treated as follows:

$$150 \times 180 \text{ feet} = 27,000 \text{ square feet, which is equal to } 0.62 \text{ acres } (27,000 \div 43,560)$$

2. Calculate the amount of water needed to cover 0.62 acres, using this formula:

$$\frac{40 \text{ gallons}}{1 \text{ acre}} = \frac{Y \text{ gallons}}{0.62 \text{ acre}}$$

which is read as "40 gallons is to one acre as Y gallons is to 0.62 acre."

Cross-multiplying:

$$(Y \times 1) = (40 \times 0.62) = 24.8 \text{ gallons to treat } 0.62 \text{ acre}$$

3. With a 4-gallon tank, we will need more than six loads of solution; let's plan to mix seven loads.

$$\frac{24.8 \text{ gallons}}{7 \text{ loads}} = 3.54 \text{ gallons per load}$$

4. If we were spraying an acre, we would need 12 pounds of pesticide per 40 gallons of water (the per-acre output of our sprayer). However, we will be spraying only 3.54 gallons at a time. To determine the amount of pesticide to add per tank load, use the following formula:

$$\frac{12 \text{ pounds}}{40 \text{ gallons}} = \frac{Y \text{ pounds}}{3.54 \text{ gallons}} =$$

$$Y = \frac{12 \times 3.54}{40} = 1.06 \text{ pounds of Pesticide B in each tank load of } 3.54 \text{ gallons}$$

## Liquid Application on a Percentage Basis

Occasionally pesticide recommendations are expressed as amount of product per a specified volume of water. Such rates are expressed as "volume/volume" equivalents or as a percentage of product in the spray solution.

**Example: Rate expressed as volume per volume.** Pesticide C is recommended as a sanitary bin spray to control stored grain insects. Four gallons of product are recommended per 100 gallons of water. You want to prepare 75 gallons of solution. How much Pesticide C do you mix with the 75 gallons of water?

$$\frac{4 \text{ gallons Pesticide C}}{100 \text{ gallons water}} = \frac{Y \text{ gallons Pesticide C}}{75 \text{ gallons water}}$$

By cross multiplying:

$$100 \times Y = 75 \times 4$$

$$100 \times Y = 300$$

$$Y = \frac{300}{100} = 3 \text{ gallons of Pesticide C per } 75 \text{ gallons of water}$$

## Granular Applicator Calibration

Occasionally, granular or pelleted pesticides are used for weed control. The need for accurate calibration is just as great for granular applicators as for sprayers.

The application rate of granular applicators depends on the size of the metered opening, the speed of the agitator



or rotor, travel speed, the roughness of the site, and the flowability of the granules. The flow rate of granules depends on particle size, density, type of granule, temperature, and humidity. The manufacturer's suggested setting should be used only as the initial setting for verification runs by the operator prior to use. A different applicator setting may be necessary for each pesticide applied; variations in flow rate also can occur with the same product from day to day or from site to site. It is therefore important to calibrate frequently to maintain the proper application rate.

Apart from the actual setting of the metering opening, ground speed is the most significant factor affecting the application rate. You must use the same ground speed during calibration that you intend to use during the application, and the speed must remain constant. However, gravity-flow applicators use a rotating agitator, with speed varying with ground speed. The flow of granules through the opening is not necessarily proportional to speed. A speed change of 1 mile per hour may cause a significant variation in the application rate.

## Drop-through Spreaders

Drop-through spreaders usually are calibrated using catch pans. Chain or wire catch pans beneath the spreader to collect granules as they are discharged. After covering a distance equivalent to 1/50 acre (871 sq. ft.), weigh the granules collected in the catch pan to determine the application rate. Use the table below to select the appropriate travel distance for your spreader.

Swath width (feet)	Travel distance (feet)
1.5	581
2	436
3	290
4	218
5	174
6	145
7	124
8	109
9	97
10	87
11	79
12	73
15	58

If your spreader has a different width, use this formula to calculate the travel distance:

$$\text{travel distance in feet} = \frac{871}{\text{swath width in feet}}$$

For example, if you have a spreader that covers a 6.5-foot swath, the distance to travel is:

$$\frac{871}{6.5} = 134 \text{ feet}$$

The step-by-step procedure for calibrating a drop-through spreader is:

1. Before starting, calculate how much material should be applied in the calibration area. You need to know only the recommended rate per acre and multiply this value by 1/50 (remember you will cover 1/50 acre in the calibration exercise).
2. Measure out the travel distance as determined by the swath width of the spreader.
3. Securely attach a collection pan to the spreader.
4. Set the feeder gate control to the setting recommended in the owner's manual or on the product label.
5. Calibrate with the same granules you intend to use during application.
6. Operate the spreader in the premeasured calibration area at the speed you intend to use during application.
7. Weigh the amount of granules in ounces in the collection pan. Be sure to use a scale that can accurately measure to the nearest ounce.
8. Compare the amount of product collected in the calibration area with the amount calculated in Step 1 above. If they are within 5 percent of each other, the applicator is properly calibrated; if not, you need to adjust the feeder gate control and recalibrate.

**Example:** A broadcast application of Pesticide D is to be made at a rate of 60 pounds of product per acre. Your equipment broadcasts granules in a 15-foot swath width. After covering a distance of 58 feet, you collect 16 ounces of granules. Is your applicator properly calibrated?

1. Determine the amount of product in ounces that should be applied to the calibration area:  
(60 pounds) x (1/50) = 1.2 pounds x 16 ounces per pound = 19.2 ounces
2. Determine if the amount actually applied (16 ounces) is within 5 percent of the recommended rate (19.2 ounces):  
19.2 ounces x 0.05 (5%) = 0.96 ounces

If your applicator was properly calibrated, it should have applied between 18.2 and 20.2 ounces of product to the calibration area. It actually applied less. You therefore need to adjust the feeder gate control to apply more material and then recalibrate.

**CHAPTER  
4**

# Review Questions

## Chapter 4: Calibration

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. Why is calibration of various spray systems essential?
  - A. True
  - B. False
2. Calibration ensures that the correct amount of pesticide is delivered uniformly over the target area.
  - A. True
  - B. False
3. What happens to the flow rate if you increase the nozzle pressure or use a larger nozzle tip opening?
  - A. Has no effect of the flow rate.
  - B. Increases the flow rate.
  - C. Decreases the flow rate.
4. To double the flow rate, you must increase the pressure:
  - A. Twofold.
  - B. Threefold.
  - C. Fourfold.
  - D. Fivefold.
5. If the throttle setting remains constant, and the speed doubles, the amount of spray per acre:
  - A. Remains constant.
  - B. Doubles
  - C. Is reduced by half.
  - D. Is reduced by one quarter.
6. Measuring and comparing the output of each nozzle to the average output of all the nozzles allows you to determine if:
  - A. The pump is functioning properly.
  - B. Any nozzle is worn or clogged.
  - C. It is the right nozzle for the job.
  - D. The pressure is accurate.
7. If the spray pattern is not uniform, you should:
  - A. Check the boom height.
  - B. Check the spacing and alignment of the nozzles on the boom.
  - C. Check the operating pressure.
  - D. Do all of the above.
8. You determine the distance to travel for calibration by:
  - A. Using a formula with a constant and the nozzle spacing.
  - B. Reading it from the pesticide label.
  - C. Reading it from the tractor handbook.
  - D. Setting an arbitrary distance based on the type of pesticide.
9. Why is there an operating pressure range for each type of nozzle?
  - A. To prevent nozzle clogging.
  - B. To relieve strain on the pump.
  - C. To keep the spray pattern from distorting.
  - D. To calculate the travel distance.
10. In a broadcast sprayer calibration, if the nozzle spacing is 30 inches, what is an appropriate distance to stake out in the field?
  - A. 101 feet
  - B. 136 feet
  - C. 256 feet
  - D. 1 acre
11. In Question 10, it took 20 seconds to travel the appropriate distance. What does this travel time tell you?
  - A. How long you should measure the output from nozzles.
  - B. How long it will take to spray the entire field.
  - C. How long it will take to empty the tank.
  - D. Whether the sprayer is properly calibrated.

12. When calibrating a broadcast sprayer, you find that the average nozzle output is 25 ounces for the recorded travel time. What is the spray rate in gallons per acre?
- A. 25 gallons per acre
  - B. 30 gallons per acre
  - C. 35 gallons per acre
  - D. 40 gallons per acre
13. What can you do if your calibrated spray rate is less than the recommended rate stated on the label?
- A. Increase the pressure.
  - B. Decrease travel speed.
  - C. Increase nozzle tip size.
  - D. B and/or C.
14. In a broadcast sprayer application, if the spray tank capacity is 150 gallons and the spray rate is 30 gallons per acre, how many acres can be sprayed per tank?
- A. 0.2 acres
  - B. 0.5 acres
  - C. 3 acres
  - D. 5 acres
15. In Question 14, how much pesticide will you need to add per tank if the label recommends 4 quarts of product per acre?
- A. 10 quarts
  - B. 20 quarts
  - C. 30 quarts
  - D. 40 quarts
16. How do you determine what rate of pesticide to apply?
- A. Use a formula.
  - B. Read it off the spray tank.
  - C. Read the pesticide label.
  - D. All of the above.
17. The flow rate of dry granular pesticide products:
- A. Varies because of many factors such as particle size and humidity.
  - B. Remains constant from product to product.
  - C. Prevents accurate calibration.
  - D. Allows for less frequent calibration than liquid products.
18. A broadcast application of granular pesticide is to be made at the rate of 30 pounds of product per acre. Your equipment broadcasts granules in a 10-foot swath. How many feet do you travel to calibrate your spreader?
- A. 218 feet
  - B. 145 feet
  - C. 87 feet
  - D. 58 feet