Calibrating Chemical Application Equipment

PURPOSE
To determine if the proper amount of chemical is being applied, the operator must measure the output of the application equipment. This technique is known as calibration. Calibration not only ensures accuracy, a critical factor with regard to many chemicals, but it can also save time and money and benefit the environment.

GETTING STARTED
Careful and accurate control of ground speed is important for any type of chemical application procedure. From large self-propelled sprayers and spreaders to small walk-behind or backpack units, precise ground speed is a key for success. Ground speed can be determined by one of two methods. The first method requires a test course and stopwatch. For this procedure, measure a suitable test course in the field and record the time it takes to cover the course with the equipment. The course should be between 100 and 300 feet long. Drive or walk the course at least twice, once in each direction and average the times for greater accuracy. Calculate the speed with Equation 1 below.

Equation 1. Ground Speed (MPH) =
\[
\text{Distance x 60} \\
\text{Seconds x 88}
\]

The second method is to use a true ground speed indicator such as a tractor-mounted radar or similar system. Do not rely on transmission speed charts and engine tachometers. They are not accurate enough for calibration.

CALIBRATING A SPRAYER: PREPARING TO CALIBRATE
For calibration to be successful, several items need to be taken care of before going to the field. Calibration will not be worthwhile if the equipment is not properly prepared. Whenever possible, calibration should be performed using water only. If you must calibrate using spray mixture, calibrate the equipment on a site listed on the chemical label and with wind speeds less than 5 MPH. Follow the steps outlined below to prepare spraying equipment for calibration.

1. Inspect the sprayer. Be sure all components are in good working order and undamaged. On backpack sprayers, pay particular attention to the pump, control wand, strainers, and hoses. On boom sprayers, pay attention to the pump, control valves, strainers, and hoses. On airblast sprayers, be sure to inspect the fan and air tubes or deflectors as well. Be sure there are no obstructions or leaks in the sprayer.

2. Check the label of the product or products to be applied and record the following:
   - **Application Rate**, Gallons per Acre (GPA)
   - **Nozzle Type**, droplet size and shape of pattern

3. Next, determine some information about the sprayer and how it is to be operated. This includes:
   - **Type of Sprayer**: backpack, boom, or airblast. The type of sprayer may suggest the type of calibration procedure to use.
   - **Nozzle Spacing (inches)**: for broadcast applications, nozzle spacing is the distance between nozzles.
   - **Nozzle Spray Width (inches)**: For broadcast applications, nozzle spray width is the same as nozzle spacing—the distance between nozzles. For band applications, use the width of the sprayed band if the treated area in the band is specified on the chemical label; use nozzle spacing if the total area is specified. For directed spray applications, use the row spacing divided by the number of nozzles per row. Some directed spray applications use more than one type or size of nozzle per row. In this case, the nozzles on each row are added together and treated as one. Spray width would be the row spacing.

   In most cases, a backpack sprayer uses a single nozzle. Some sprayers use mini-booms or multiple nozzles. The spray width is the effective width of the area sprayed, being sure to account for overlap. If you are using a sweeping motion from side to side, be sure to use the full width sprayed as you walk forward. If you are spraying on foliage in a row, use the row spacing. Dyes are available to blend with the spray to show what has been covered.

   - **Spray Swath (feet)**: The width covered by all the nozzles on the boom of a sprayer. For airblast or other boomless sprayers, it is the effective width covered in one pass through the field.

   - **Ground Speed, miles per hour (MPH)**. When using a backpack sprayer, walk a comfortable pace that is easy to maintain. Slow walking speeds will take longer to complete the task while high speeds may be tiresome. Choose a safe, comfortable speed that will enable you to finish the job in a timely manner. On tractor-mounted sprayers, select a ground speed appropriate for the crop and type of sprayer used. Slow speeds will take longer to complete the task, while high speeds may be difficult to control and unsafe. Choose a safe, controllable speed that will enable you to finish the job in a timely manner. Ground speed can be determined from Equation 1.
4. The discharge rate, gallons per minute (GPM), required for the nozzles must be calculated in order to choose the right nozzle size. Discharge rate depends on the application rate; ground speed; and nozzle spacing, spray width, or spray swath.

For applications using nozzle spacing or nozzle spray width (inches), use Equation 2.

\[
\text{Equation 2. Discharge Rate} = \frac{\text{Application Rate} \times \text{Ground Speed} \times \text{Nozzle Spray Width}}{5,940}
\]

For applications using the spray swath (feet):

\[
\text{Equation 3. Discharge Rate} = \frac{\text{Application Rate} \times \text{Ground Speed} \times \text{Spray Swath}}{495}
\]

5. Choose an appropriate nozzle or nozzles from the manufacturer’s charts and install them on the sprayer. Check each nozzle to be sure it is clean and that the proper strainer is installed with it.

6. Fill the tank half full of water and adjust the nozzle pressure to the recommended setting. Measure the discharge rate for the nozzle. This can be done by using a flow meter or by using a collection cup and stopwatch. The flow meter should read in gallons per minute (GPM). If you are using the collection cup and stopwatch method, the following equation is helpful to convert ounces collected and collection time, in seconds, into gallons per minute.

\[
\text{Equation 4. Discharge Rate} = \frac{\text{Ounces Collected} \times 60}{\text{Collection Time} \times 128}
\]

7. Whenever possible, calibrate with water instead of spray solution. Do not calibrate with spray solution unless required by the chemical label. Follow all recommendations on the label. If the spray solution has a density different than water, the rate can be corrected using the procedure shown in Calibration Variables.

8. On boom sprayers or sprayers with multiple nozzles, average the discharge rates of all the nozzles on the sprayer. Reject any nozzle that has a bad pattern or that has a discharge rate 10 percent more or less than the overall average. Install a new nozzle to replace the rejected one and measure its output. Calculate a new average and recheck the nozzles compared to the new average. Again, reject any nozzle that is 10 percent more or less than the average or has a bad pattern. When finished, select a nozzle that is closest to the average to use later as your “quick check” nozzle.

On backpack sprayers or sprayers with a single nozzle, compare the discharge rate of the nozzle on the sprayer to the manufacturer’s tables for that nozzle size. Reject any nozzle that has a bad pattern or that has a discharge rate 10 percent more or less than the advertised rate. Install a new nozzle to replace the rejected one and measure its output.

Once the sprayer has been properly prepared for calibration, select a calibration method. When calibrating a sprayer, changes are often necessary to achieve the application rates needed. The sprayer operator needs to understand the changes that can be made to the adjust rate and the limits of each adjustment. The adjustments and the recommended approach are:

- **Pressure**: if the error in application rate is less than 10 percent, adjust the pressure.
- **Ground speed**: if the error is greater than 10 percent but less than 25 percent, change the ground speed of the sprayer.
- **Nozzle size**: if the error is greater than 25 percent, change nozzle size. The goal is to have application rate errors less than 5 percent.

**Calibration Methods**

There are four methods commonly used to calibrate a sprayer:

The basic, nozzle, and 128\textsuperscript{a} acre methods are “time-based methods” which require using a stopwatch or watch with a second hand to ensure accuracy. The area method is based on spraying a test course measured in the field. Each method offers certain advantages. Some are easier to use with certain types of sprayers. For example, the basic and area methods can be used with any type of sprayer. The 128\textsuperscript{a} acre and nozzle methods work well for boom and backpack sprayers. Choose a method you are comfortable with and use it whenever calibration is required.

**BASIC METHOD**

1. Accurate ground speed is very important to good calibration with the basic method. For tractor-mounted sprayers, set the tractor for the desired ground speed and run the course at least twice. For backpack sprayers, walk the course and measure the time required. Walk across the course at least twice. Average the times required for the course distance and determine ground speed from Equation 1.

2. Calculate the application rate based on the average discharge rate measured for the nozzles, the ground speed over the test course, and the nozzle spacing, nozzle spray width, or spray swath on the sprayer.

When using nozzle spacing or nozzle spray width measured in inches, use the following equation:

\[
\text{Equation 5. Application Rate} = \frac{5,940 \times \text{Discharge Rate}}{\text{Ground Speed} \times \text{Nozzle Spray Width}}
\]

For spray swath applications measured in feet:

\[
\text{Equation 6. Application Rate} = \frac{495 \times \text{Discharge Rate}}{\text{Ground Speed} \times \text{Spray Swath}}
\]

3. Compare the application rate calculated to the rate required. If the rates are not the same, choose the appropriate adjustment and reset the sprayer.

4. Recheck the system if necessary. Once you have the accuracy you want, calibration is complete.
NOZZLE METHOD

1. Accurate ground speed is very important to good calibration with the nozzle method. For tractor-mounted sprayers, set the tractor for the desired ground speed and run the course at least twice. For backpack sprayers, walk the course and measure the time required. Walk across the course at least twice. Average the times required for the course distance and determine ground speed from Equation 1.

2. Calculate the nozzle discharge rate based on the application rate required the ground speed over the test course, and the nozzle spacing, spray width, or spray swath of the sprayer. For nozzle spacing or spray width measured in inches:

\[
\text{Equation 7. Discharge Rate} = \frac{\text{Application Rate} \times \text{Speed} \times \text{Spray Width}}{5,940}
\]

For spray swath measured in feet:

\[
\text{Equation 8. Discharge Rate} = \frac{\text{Application Rate} \times \text{Speed} \times \text{Spray Swath}}{495}
\]

Set the sprayer and determine the average nozzle rate.

3. Compare the rate calculated to the average rate from the nozzles. If the two don’t match, choose the appropriate adjustment and reset the system.

4. Recheck the system if necessary. Once you have the accuracy you want, calibration is complete.

128TH ACRE METHOD

1. The distance for one nozzle to cover 128\(^{th}\) of an acre must be calculated. The nozzle spacing or spray width in inches is used to determine the spray distance. Spray distance is measured in feet. On backpack sprayers, be sure to measure the full width sprayed as you walk forward. Use Equation 9.

\[
\text{Equation 9. Spray Distance} = \frac{4,084}{\text{Spray Width}}
\]

2. Measure the spray distance on a test course in the field. Check the ground speed as you travel across the course. Be sure to maintain an accurate and consistent speed. Travel the course at least twice and average the time to cover the course.

3. For backpack sprayers, collect the output from the nozzle for the time measured in step 2. For tractor-mounted sprayers, park the sprayer, select the nozzle closest to the average, and collect the output for the time determined in step 4. Ounces collected will equal application rate in GPA.

4. Compare the application rate measured for the nozzle to the rate determined in step 3. If the rates are not the same, choose the appropriate adjustment and reset the system.

5. Recheck the system if necessary. Once you have the accuracy you want, calibration is complete.

AREA METHOD

1. Determine the distance that can be sprayed by one tank using the full spray swath measured in feet.

\[
\text{Equation 10. Tank Spray Distance (ft)} = \frac{\text{Tank Volume (gal)} \times 43,560}{\text{Application Rate (GPA)} \times \text{Swath (ft)}}
\]

2. Lay out a test course that is at least 10 percent of the tank spray distance from Step 1. Fill the sprayer tank with water only, mark the level in the tank, set the sprayer as recommended, and spray the water out on the course. Be sure to maintain an accurate and consistent speed.

3. After spraying the test course, carefully measure the volume of water required to refill the tank to the original level. Calculate the application rate as shown:

\[
\text{Equation 11. Application Rate (GPA)} = \frac{\text{Volume Sprayed (gal)} \times 43,560}{\text{Test Course Distance (ft)} \times \text{Swath (ft)}}
\]

4. Compare the application rate measured to the rate required. If the rates are not the same, choose the appropriate adjustment method and reset the sprayer.

5. Recheck the system. Once you have the accuracy you want, calibration is complete.
CALIBRATING A GRANULAR APPLICATOR:
PREPARING TO CALIBRATE

Granular application calibration is usually done with the chemical to be applied. It is difficult to find a blank material that matches the granular product. Extra care should be taken in handling this product. Minimize worker exposure and take precautions against spills during calibration.

To prepare for calibration, follow these steps:

1. Before calibrating, carefully inspected the equipment to ensure that all components are in proper working order. Check the hopper, the metering rotor, the orifice, and the drop tubes. Be sure there are no leaks or obstructions.
2. Determine the type of application required for the product:
   - Broadcast: treats the entire area (includes band applications based on broadcast rates).
   - Band: treats only the area under the band.
   - Row: treats along the length of the row.
3. Determine the application rate needed:
   - Broadcast: pounds per acre.
   - Band: pounds per acre of treated band width.
   - Row: pounds per acre or pounds per 1,000 feet of row length.
4. What type of drive system does the applicator use?
   - Independent: uses PTO, hydraulic, or electric motor drive.
   - Ground Drive: uses ground driven wheel.
5. Regardless of how the application rate is expressed or type of application, calibration is easier if the rate is expressed in terms of pounds per foot of row length. Use one of the following steps to determine the correct row rate in pounds per foot.

   - For broadcast and row applications
     \[ \text{Row Rate, lb/ft} = \frac{\text{Application Rate} \times \text{Row Width (ft)}}{43,560} \]

   - For banded applications
     \[ \text{Row Rate, lb/ft} = \frac{\text{Application Rate} \times \text{Band Width (ft)}}{43,560} \]

6. Choose a calibration distance to work with and measure a test course of this distance in the field you will be working in. Choose an area that is representative of field conditions.

7. Calculate the weight of material that should be collected for the calibration distance chosen.

   \[ \text{Equation 15. Weight Collected} = \frac{\text{Row Rate} \times \text{Calibration Distance}}{} \]

8. Select a ground speed appropriate for the crop and type of equipment used. Slow speeds take longer to finish the task, while high speeds may be inefficient and unsafe. Consult your equipment manual for a recommended speed. Even ground-driven application equipment can be sensitive to changes in speed. Maintaining an accurate and consistent speed is very important. Choose a safe, controllable speed that will enable you to complete the job in a timely and efficient manner.

9. Set your equipment according to recommendations from the equipment or chemical manufacturer. Most equipment manufacturers and chemical manufacturers provide rate charts to determine the correct orifice setting or rotor speed for each applicator. Fill the hopper at least half full to represent average capacity for calibration.

10. Attach a suitable collection container to each outlet on the applicator. You should be able to collect all material discharged from the applicator. Locate a scale capable of weighing the samples collected in calibration. Some samples may be very small, so a low-capacity scale may be needed. An accurate scale is very important.

Calibration Methods

Two methods for calibrating granular applicators are commonly used. The first is the distance method. This method is preferred by many operators because it applies to any type of granular machine and is easy to perform. The second method is the time method. This method is similar to sprayer calibration and can be used for applicators driven by PTO, hydraulic, or electric motors.

DISTANCE METHOD

1. On the test course selected in the field, collect the output from the applicator in a container as you travel the course and weigh the material collected. Record the time required to travel the course also. Run the course twice, once in each direction, and average the results for both weight and time.

2. Determine the weight of the product that should be collected for the calibration distance.

   \[ \text{Equation 16. Weight Collected (lb)} = \frac{\text{Row Rate (lb/ft)} \times \text{Calibration Distance (ft)}}{} \]

3. Compare the weight of the product actually collected to the weight expected for the calibration distance. If the rates differ by more than 10 percent, adjust the orifice, rotor speed, or ground speed and repeat. Bear in mind, speed adjustments are not effective for ground-driven equipment.

4. Repeat the procedure until the error is less than 10 percent.
TIME METHOD

1. On the test course selected in the field, record the time required to travel the course. Run the course twice, once in each direction, and average the results. Accurate ground speed is very important to good calibration with the time method.

2. With the equipment parked, set the orifice control as recommended and run the applicator for the time measured to run the calibration distance. Collect and weigh the output of the applicator for this time measurement.

3. Determine the weight of the product that should be collected for the calibration distance.

**Equation 17. Weight Collected (lb) =**
\[
\text{Row Rate (lb/ft)} \times \text{Calibration Distance (ft)}
\]

4. Compare the weight of the product actually collected during the time it took to cover the calibration distance to the weight expected for the calibration distance. If the rates differ by more than 10 percent, adjust the orifice, rotor speed, or ground speed and repeat. Bear in mind, speed adjustments are not effective for ground-driven equipment.

5. Repeat the procedure until the error is less than 10 percent.

CALIBRATING A BROADCAST SPREADER: PREPARING TO CALIBRATE

Broadcast spreaders include machines designed to apply materials broadcast across the surface of the field. They include drop, spinner, and pendulum spreading devices. Calibration of a broadcast spreader is usually done using the product to be applied. Blank material is available and can be used, but may be hard to find. Use extra care and preparation when calibrating with the chemical. To begin, follow these steps:

1. Carefully inspect all machine components. Repair or replace any elements that are not in good working order.

2. Determine the type of drive system that is being used: ground drive or independent PTO. This may help determine the method of calibration.

3. Determine the application rate and the bulk density of the product to be applied.

4. Determine the spreader pattern and swath of the spreader. Check the pattern to ensure uniformity. To check the pattern, place collection pans across the path of the spreader. For drop spreaders, be sure to place a pan under each outlet. For centrifugal and pendulum spreaders, space the pans uniformly with one in the center and an equal number on each side. The pattern should be the same on each side. The pattern should be uniformly spaced to cover the full swath. The swath would be set as the width from side to side where a pan holds 50 percent of the maximum amount collected in the center pan.

5. Fill the hopper half full to simulate average conditions.

6. Set the ground speed of the spreader.

7. Set the spreader according to the manufacturer’s recommendations and begin calibration.

**Calibration Methods**

There are two common methods used to calibrate broadcast spreaders. The first method is the discharge method. To use this procedure, collect and measure the total discharge from the spreader as it runs across a test course. The second method, the pan method, is used on centrifugal and pendulum spreaders. The pattern test pans used to determine pattern shape and swath are used to determine the application rate.

**DISCHARGE METHOD**

1. Determine the test distance to use. Longer distances may give better accuracy but may be difficult to manage. A distance of 300 to 400 feet is usually adequate. Use shorter distances if necessary to avoid collecting more material than you can reasonably handle or weigh.

2. Set the ground speed. Be sure to maintain a constant ground speed at all times.

3. If using a ground drive spreader, attach a collection bin to the discharge chute or under the outlets and collect all the material discharged from the spreader as it runs across the test distance. If using an independent drive spreader, record the time required to run the test course. Park the spreader at a convenient location and measure the discharge from the spreader for the time measured on the test distance. The course should be run twice and the times averaged for better accuracy.

4. Calculate the application rate (pounds per acre):

**Equation 18. Application Rate, lb/ac =**
\[
\frac{\text{Weight Collected (lb)} \times 43,560}{\text{Distance (ft)} \times \text{Swath (ft)}}
\]

5. Compare the application rate measured to the rate required. Adjust and repeat as necessary.

**PAN METHOD**

1. Place pans in the field across the swath to be spread. Pans should be uniformly spaced to cover the full swath. One pan should be at the center of the swath with equal numbers of pans on each side. Use enough pans, 11 or more, to get a good measurement.

2. Make three passes with the spreader using the driving pattern to be used in the field. One pass should be directly over the center pan and the other passes at the recommended distance, lane spacing, to the left and right of the center pass.

3. Combine the material collected in the pans and determine the weight or volume collected. Divide by the number of pans used to determine the average weight or volume per pan.

4. Calculate the application rate.
If you are measuring the weight in the pans in grams:

**Equation 19. Application Rate, lb/ac =**

\[
\frac{13,829 \times \text{Weight (grams)}}{\text{Pan Area (inches}^2)}
\]

If you are measuring the volume in the pans in cubic centimeters (cc):

**Equation 20. Application Rate, lb/ac =**

\[
\frac{13,829 \times \text{Bulk Density (lb/ft}^3) \times \text{Volume (cc)}}{\text{Pan Area (inches}^2) \times 62.4}
\]

5. Compare the rate measured to the rate required.

### CALIBRATION VARIABLES

Several factors can affect proper calibration. The ground speed of any type of PTO-powered machine can make a difference. On the other hand, ground-driven machines are usually only slightly affected by changes in ground speed. If using dry or granular material, product density will affect the discharge rate and may change the pattern for broadcast spreaders. For liquids, calibration can be affected by pressure, nozzle size, density and viscosity of the liquid, and application type—band or broadcast. The following adjustments may help in adjusting these variables.

### SPEED

For PTO-powered equipment or other equipment in which the discharge rate is independent of ground speed, Equation 10 is useful.

**Equation 21. New Application Rate =**

\[
\text{Old Application Rate} \times \left( \frac{\text{Old Speed}}{\text{New Speed}} \right)
\]

For ground-driven equipment, there should be little or no change in application rate when speed is changed.

### PRESSURE

For liquids in sprayers, the discharge rate changes in proportion to the square root of the ratio of the pressures.

**Equation 22. New Discharge Rate =**

\[
\text{Old Discharge Rate} \times \sqrt{\frac{\text{New Pressure}}{\text{Old Pressure}}}
\]

### DENSITY

For liquids in sprayers, the discharge rate changes if the specific gravity (S.G.) of the liquid changes. Use water for calibration and adjust as shown below. Calibrate with spray solution only if recommended by the supplier.

**Equation 23. Water Discharge Rate =**

\[
\text{Spray Discharge Rate} \times \sqrt{\text{S.G. of Spray Solution}}
\]

### BAND APPLICATION VERSUS BROADCAST APPLICATION

Some pesticide application recommendations are based on area of cropland covered. Other recommendations are based on area of land treated in the band covered. Check the label for the product you are using to see how it is listed.

Broadcast application is based on area of cropland covered. Nozzle spacing is the distance between nozzles. Band applications in which the area of covered cropland is used for calibration and those applications in which multiple nozzles per row are used are both treated like broadcast applications. Divide the row spacing by the number of nozzles used per row to get a nozzle spacing for calibration.

For band applications in which area of treated land—not cropland covered—is specified, use the width of the band at the ground as the spacing for calibration.

### DETERMINING UPPER AND LOWER LIMITS

Upper and lower limits provide a range of acceptable error. To set these limits for a given sample size, use the equations below. First, however, you must decide upon the degree of accuracy you wish to achieve. Select a percent error: 2 percent, 5 percent, 10 percent, or any other level of accuracy.

**Equation 24. Upper Limit =**

\[
\text{Target Rate} \times (1 + \frac{\text{Percent Error}}{100\%})
\]

**Equation 25. Lower Limit =**

\[
\text{Target Rate} \times (1 - \frac{\text{Percent Error}}{100\%})
\]