AGRICULTURE AND NATURAL RESOURCES FABE-529

Calibrating Boom Sprayers for Forestry Herbicide Application

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Applying herbicides at the proper rate is essential to achieving satisfactory weed control. The directions on the container label tell a user which application rates give the best results. However, proper application rates will be attained only if sprayers work well and are calibrated correctly.

Good tree seedling survival and growth usually requires control of competing vegetation (weeds) at planting time and for several years thereafter. Herbicides are often the most economical and effective method to accomplish short- and long-term weed control. Many herbicides used in forestry are applied with a sprayer and their accurate application at prescribed rates requires calibration of the sprayer. If the sprayer is not accurately calibrated, too little or too much herbicide may be applied, resulting in unsatisfactory weed control, or damage or death of the seedlings.

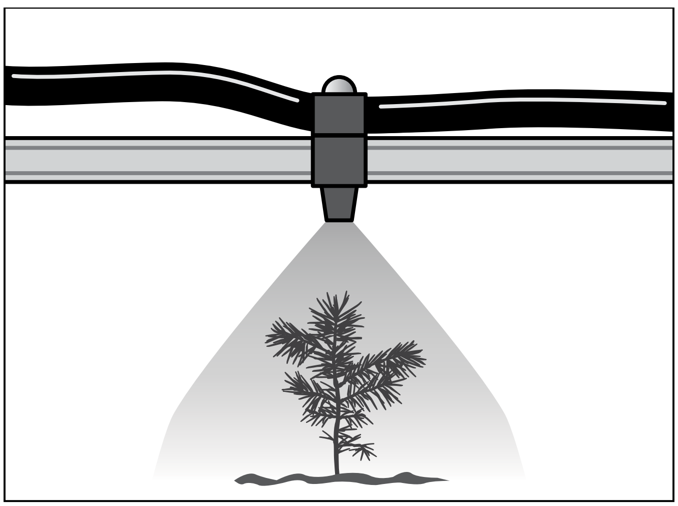
In Ohio, herbicides applied to young tree seedlings are usually applied in bands along tree rows or in circles around the base of the trees, rather than over the entire ground area. Only a fraction of each acre is actually sprayed. Many different configurations and types of tractor-drawn sprayers can be used to spray herbicides in bands including: fixed boom with one or more nozzles; hose and spray gun operated by a person walking; and a hose with small hand-held booms.

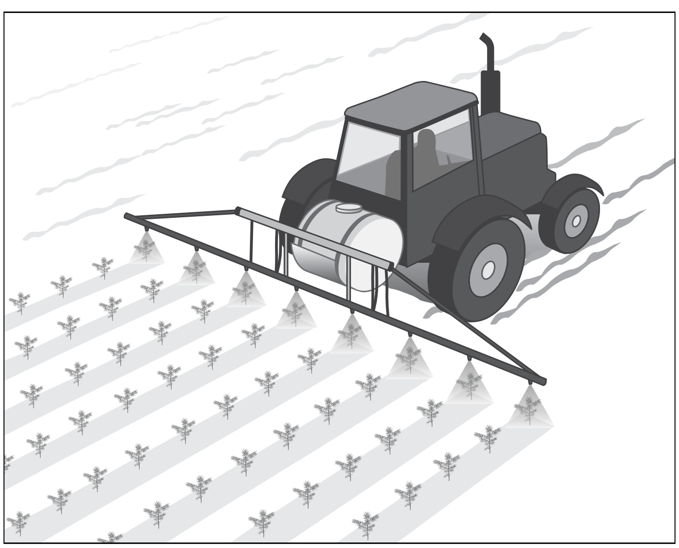
This fact sheet describes the steps and considerations for calibrating boom sprayers that are either tractor-drawn or on a small utility vehicle such as an ATV or UTV. Calibration of hand can or backpack sprayers is discussed in fact sheet FABE-531, “Proper Calibration and Operation of Backpack and Hand Can Sprayers,” another Ohio State University Extension fact sheet available online at **ohioline.osu.edu/factsheet/fabe-531**. Determining the amount of herbicide required to spray a specific tree planting is discussed in Extension fact sheet FABE-530, **ohioline.osu.edu/factsheet/fabe-530**. There are several ways to calibrate a sprayer.

Use the one calibration method that you are accustomed to, if it happens to be different than the procedure outlined in this publication. Regardless of the method used to calibrate a sprayer, certain measurements will have to be taken, and some important factors mentioned in this fact sheet should be taken into consideration to achieve maximum efficacy from the chemical applied.

Determine the Volume of Spray Delivered by Nozzles

Single Nozzle Per Band





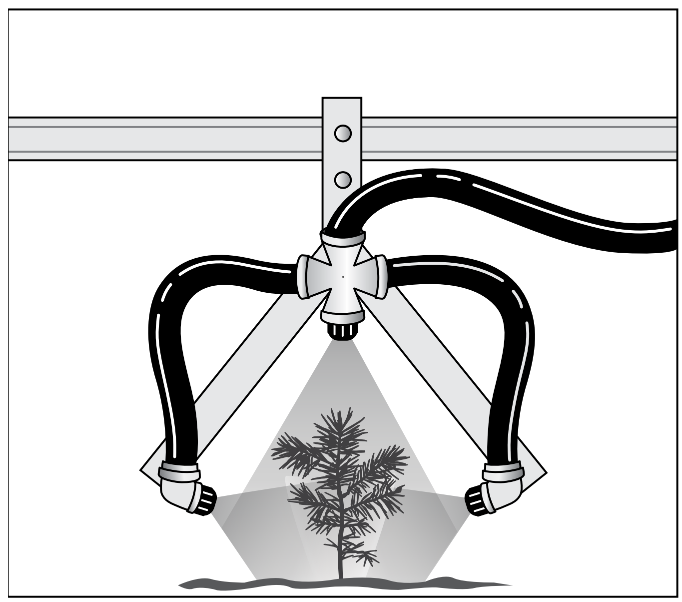
With the sprayer stationary, and the operating pressure set to the same pressure that will be used in the field, place a measuring cup with a capacity of at least 1 quart and graduated in liquid ounces under each nozzle and collect spray for a pre-determined time (in seconds) from each nozzle. The flow rate in gallons per minute (GPM) for each nozzle is then determined as follows:

$$\text{GPM} = \frac{\text{Liquid collected (in ounces)} \times 60}{\text{Collection time (in seconds)} \times 128}$$

Example: With the sprayer stationary and operating at the pressure to be used in the field, 21 ounces is collected in the calibration cup in 40 seconds. The GPM delivery rate of the nozzle is:

$$\text{GPM} = 21 \times 60 / 40 \times 128 = 0.25 \text{ gallons per minute}$$

Multiple Nozzles Per Band (Overlapping Spray Pattern)



If multiple nozzles are used to spray a single row, determine the delivery rate of each nozzle in GPM as explained above, and add the amounts together to obtain the total amount of spray in GPM being delivered to the row.

Example: The spray boom to be used is configured so that two nozzles with overlapping patterns are used to spray a single row. The flow rate of one nozzle is 0.25 GPM, and the other is 0.29 GPM. The total volume of spray delivered to the band is 0.54 GPM.

Replace Bad Nozzles

After calculating the GPM of each nozzle, check to see if any of the nozzles should be replaced. To do this, find out the flow rate of same type and size of nozzles when they are new. This information can be found in catalogs provided by the nozzle manufacturers, or on their website. Compare the flow rate of each nozzle you determined at a given spray pressure with the flow rate listed in the nozzle catalog for that nozzle at the same pressure. If the flow rate of any nozzle is more than 10 percent higher than the flow rate of the new nozzle at the same operating pressure listed in the catalog, consider that nozzle as "worn-out" and replace it with a new one of the same capacity. In case of under spraying, consider cleaning the nozzle and the nozzle strainer (mesh screen) with a soft brush, reinstall, and measure the flow rate again. If cleaning does not bring the error margin between the new and the old nozzle within 10 percent of the new nozzle flow rate, the nozzle should be replaced with a new one of the same capacity.

Example: The nozzles on a four-nozzle boom deliver 42, 47, 50, and 56 ounces/minute (OPM) at 40 PSI spray pressure. The nozzle catalog indicates that a new nozzle of the same type and capacity has a flow rate of 50 OPM at the same spray pressure. Do any of these four nozzles need to be replaced?

First, determine the +/- 10 percent error margin of the new nozzle. Ten percent of 50 OPM is 5 OPM. This means any nozzle with a flow rate of 45 to 55 OPM is considered a good nozzle that does not need to be replaced. In this example, two nozzles (the ones with flow rates of 42 and 56 OPM) should be inspected (low flow; 42 OPM), and replaced (high flow; 56 OPM).

Once the "bad" nozzles are replaced with the new nozzles, determine the final GPM per row by adding the individual GPM nozzle outputs together and dividing this total GPM by the number of nozzles per row. Use the average GPM when determining the application rate in gallons per acre.

Determine Travel Speed

Measure a known distance, preferably at least 150 feet. Drive this distance while operating the vehicle the same as it would be operated in the actual spraying (at normal miles per hour (MPH) speed, and revolutions per minute (RPM) of the Power Take-Off (PTO) if a tractor is used). Begin the test run from a standing start far enough ahead of the measured course so that the tractor is traveling at the desired speed before coming to the start of the course. Record the time elapsed in seconds. Repeat the driving test from the opposite direction, and determine the average of the two measurements. The travel speed in MPH is calculated as follows:

$$\text{MPH} = \frac{(\text{Distance traveled in feet}) \times (0.68)}{\text{number of seconds needed to travel pre-measured distance}}$$

Example: If it takes 29 seconds to travel 150 feet, the travel speed is 3.5 MPH.

$$\text{MPH} = \frac{(150 \text{ feet}) \times (0.68)}{29 \text{ seconds}} = 3.5 \text{ MPH}$$

Determine the Actual Application Rate

The gallons per acre (GPA) application rate of the spray boom is determined as follows:

$$\text{GPA} = \frac{(\text{GPM}) \times (5{,}940)}{(\text{MPH}) \times (\text{W})}$$

GPM = Gallons per minute flow rate of the nozzle or nozzles on the boom. It is the flow rate of a single nozzle when only one nozzle is used per row, or the average flow rate of multiple nozzles used per row.

MPH = Travel speed (in miles per hour)

W = The width of sprayed area per nozzle (in inches) and varies depending on how you have set up your sprayer for a specific spraying job, as follows:

- For broadcast application: W is the distance in inches between two nozzles on the boom
- For band application: W is the width of the band in inches
- For directed applications (more than one nozzle is directed over one row): W is row spacing (in inches) divided by the number of nozzles used per row.

5,940 = A constant that comes out when all the units on the right side of the equation are converted to gallons per acre, the unit on the left side of the equation.

Example: Using a boom with an average nozzle spray rate of 0.25 GPM, a speed of 3.5 MPH, and spraying a 24-inch wide band, the gallons per acre application rate is as follows:

$$GPA = \frac{(0.25\ GPM)\ X\ (5{,}940)}{(3.5\ MPH)\ X\ (24\ inches)} = 17.68\ GPA$$

Evaluate Suitability of Application Rate Determined

Compare the calculated application rate with that recommended for the specific herbicide to be used (refer to label on herbicide container). If the difference between the recommended rate and the calculated rate is greater than 5 percent of the recommended rate, adjustments should be made to bring the application error within +/- 5 percent of the intended (recommended) rate. Small errors can be eliminated by adjustments in the travel speed and/or spray pressure. Do not operate the nozzles outside the pressure range recommended by the nozzle manufacturer. Similarly, excessive travel speed may not be safe and will increase spray drift risk. If reasonable speed and/or pressure changes will not bring the application error below 5 percent of the intended (or recommended) rate, the only option left to achieve the desired application rate is to replace the nozzles on the boom with the ones that will produce the desired application rate under normal operating conditions (speed and pressure) of the sprayer.

How to Eliminate the Application Error

As mentioned in the previous paragraph, adjustments are necessary when the application error exceeds 5 percent of the intended rate. You can reduce the application error below 5 percent by trial and error, each time trying a new travel speed or pressure. However, to save time, use the following equations to determine the new travel speed and/or the pressure required to bring the application error below the acceptable 5 percent margin.

- **To determine the actual travel speed in the field:**

  Distance (feet)/ Travel (seconds) X 0.68 = Travel speed (MPH)

- **To determine the appropriate travel speed (MPH) for a desired application rate (GPA):**

  a. GPA_2 X MPH_2 = GPA_1 X MPH_1

  b. MPH_2 = GPA_1 X MPH_1 / GPA_2

- **To determine the appropriate pressure (PSI) for a desired application rate (GPA):**

  a. GPA_2/GPA_1 = (square root PSI_2)/square root PSI_1

  b. $PSI_2 = PSI_1$ X $(GPA_2/GPA_1)^2$

  GPA_2, GPA_1: Desired and measured application rate, respectively (gallon per acre).

  MPH_2, MPH_1: Desired and measured travel speed, respectively (miles per hour).

  PSI_2, PSI_1: Desired and measured spraying pressures, respectively (pound per square inch)

Example: You want to spray an area at a rate of 1.25 gallons per 1,000 square feet with a boom sprayer. The sprayer is traveling at 5 mph and has a nozzle spacing of 20 inches. The average flow rate of the nozzles is 100 ounces per minute (OPM) at a pressure of 30 psi. What is the actual application rate, and the percent application error of this sprayer; and what can you do to bring the application error below 5 percent of the intended rate?

Use the following equation (discussed earlier) to determine the actual application rate of the sprayer:

$$GPA = \frac{GPM\ X\ 5{,}940}{MPH\ X\ W}$$

First, you need to convert the flow rate of nozzles from ounces per minute to gallons per minute:

$$\frac{100\ ounces}{minute}\ X\ \frac{1\ gallon}{128\ ounces} = 17.68\ GPA$$

Next, use the equation above to determine the actual application rate:

$$\frac{(0.78 \text{ GPM}) \times (5{,}940)}{(5 \text{ MPH}) \times (20 \text{ inches})} = 46.30 \text{ GPA}$$

To find the application error, you need to convert 46.3 GPA to gallons per 1,000 square feet (since the intended rate is given in gallons per 1,000 square feet).

$$\frac{46.3 \text{ gallons}}{\text{acre}} \times \frac{1 \text{ acre}}{43.56 \times 1{,}000 \text{ sq. ft.}} = \frac{1.06 \text{ gallons}}{1{,}000 \text{ sq. ft.}}$$

Actual application rate: 1.06 gal per 1,000 sq. ft.

Intended application rate: 1.25 gal per 1,000 sq. ft.

$$\text{Percent application error} = \frac{\text{intended rate} - \text{actual rate}}{\text{intended rate}} \times 100$$

$$\text{Percent application error} = \frac{1.25 - 1.06}{1.25} \times 100 = 15.2\%$$

Since the application error is greater than 5 percent of the intended rate (the sprayer is applying less in this case; applying 1.06 gallon per 1,000 square feet, instead of 1.25 gallons per 1,000 square feet), you need to make some adjustments in either the travel speed or the spray pressure, or a combination of both. Here is how you can use the equations given earlier to determine exactly what the new travel speed or the pressure must be to eliminate the application error.

1. Let's assume you want to first try changing the travel speed. What should be the new travel speed, instead of 5 mph current travel speed?

$$\text{Desired MPH} = \frac{\text{Measured application rate} \times \text{Measured MPH}}{\text{Desired application rate}}$$

$$\text{Desired MPH} = \frac{1.06 \times 5}{1.25} = 4.24 \text{ MPH}$$

2. Let's see what the new pressure rate should be if we choose the option of changing the pressure to eliminate the 15.2 percent application error.

$$\text{Desired PSI} = \text{Measured PSI} \times \frac{(\text{Desired rate})^2}{(\text{Measured rate})^2}$$

$$\text{Desired PSI} = 30 \times \frac{(1.25)^2}{(1.06)^2} = 30 \times \frac{1.56}{1.12} = 41.8 \text{ PSI}$$

These calculations show that, to correct your application error, you need to either reduce your travel speed from 5 mph to 4.24 mph, or increase the sprayer operating pressure from 30 psi to 41.8 psi. Both of these changes will eliminate the application error, and you will be able to apply exactly 1.25 gallons per 1,000 square feet, as recommended on the label.

Factors That Affect Spray Rate and Performance

While calibration of the sprayer will assure you attain the intended application rate, you need to be aware of some factors that will affect achieving your ultimate goal: maximum efficacy expected from a spraying operation. Following is a brief discussion on these factors.

Spraying Pressure

Spraying at a higher or lower pressure will result in more or less herbicide being applied as the sprayer passes over the ground. Changes in pressure will also alter the droplet size which affects spray coverage, penetration, and eventually efficacy. The only way to know if you are operating the sprayer at the recommended pressure is to have a reliable, good quality (glycerin filled) and functional pressure gauge on the sprayer. From time to time, check the accuracy of the pressure gauge by comparing it to a brand new, good quality pressure gauge.

Nozzle Type and Size

Nozzles meter the amount of liquid sprayed per unit area, controlling application rate, as well as variability of spray over the width of the sprayer boom. Nozzles also influence droplet size, affecting both target coverage and spray drift risk. Nozzles come in a wide variety of types and sizes. The best nozzle for a given application will maximize efficacy, minimize spray drift, and allow compliance with label requirements such as application rate (gallons per acre) and spray droplet size. Selecting the best

nozzle requires careful consideration of several factors, such as: sprayer operation parameters (application rate, spray pressure, travel speed); type of chemical sprayed (herbicides, insecticides, fungicides, fertilizers, and growth regulators); mode of action of chemical (systemic, contact); application type (broadcast, band, directed); target crop (field crops, vegetables, vineyard, shrubs and trees, etc.); and spray drift risk. See Extension fact sheet, FABE-528, “Selecting the Best Nozzle for the Job” for detailed information on nozzle selection **ohioline.osu.edu/factsheet/fabe-528**.

Generally, in forestry applications, even flat-fan spray nozzles are most desirable for band or spot spraying. They provide the most even distribution of spray material over the area treated. Sprayers must be calibrated for each nozzle type and size. The larger the nozzle orifice, the more spray is put out as the sprayer passes over the ground. Thus, to maintain a particular rate of application when nozzles with larger orifices are used, smaller amounts of herbicide will have to be added to the water if the travel speed is to remain the same.

Speed of Travel

Spraying should be done at a safe and practical speed. The travel speed should remain the same, as much as possible, throughout spraying the entire field. Even slight changes in speed may alter the application rate significantly. For example, you were to apply 4 gap at a speed of 4 mph, and without noticing your travel speed is 3 mph. The 1 mph reduction in speed will result in gpa application to go up from 4 to 5, an increase of 25 percent in chemical cost. Faster speeds will result in lower rates of herbicide application, which may lead to insufficient pest control and respraying the area again.

Boom Height and Nozzle Alignment

Make sure nozzles are properly aligned to apply spray uniformly where desired. Boom height, nozzle spray pattern angle, and nozzle spacing influence overlap and uniformity of spray application. Boom height affects the spray pattern overlap, deposition uniformity on the target, and the time during which the droplets are exposed to wind and evaporation, both of which directly influence drift. If nozzles require overlapping, check the nozzle catalog or instructions to determine the overlap required for specific nozzles. The proper height should be maintained at all sections of the boom. Spray release height should be kept to a minimum in order to reduce drift and should be consistent with nozzle manufacturer recommendations. The roughness of the terrain, boom dynamics, and instability also influence the effective release height of the spray. To achieve satisfactory coverage and reduce drift, consider an appropriate boom length and travel speed for the terrain.

Clogged Nozzles

A common cause of non-uniform coverage is clogged nozzles. Watch the nozzles periodically while spraying to detect clogging. Always carry tools for cleaning nozzles and extra nozzles. Replace defective nozzles immediately.

Final Thoughts

Too little pesticide results in poor pest control and reduced yields, while too much injures the crop, wastes your chemical dollars, and increases the risk of polluting the environment. Proper application rates given on product labels can be attained only if sprayers work well and are calibrated correctly. However, other factors should be considered to have a successful herbicide application. For example, you need to know how much chemical to add to the sprayer tank. If you need help in making the calculations to determine the herbicide amount to add to the tank, read the Extension fact sheet, FABE-530, available online at **ohioline.osu.edu/factsheet/fabe-530**.

Finally, always keep safety in mind when working with chemicals, especially pesticides. Although the pesticides in a spray mixture may slightly affect the flow rate and droplet size of nozzles, the effect is negligible. Therefore, for safety reasons, it is best to use clean water when calibrating sprayers. Even when using clean water for calibration, take all the safety precautions as when spraying pesticides. Always try to minimize oral, dermal, or inhalation exposure to chemicals. Wear protective clothing when calibrating, spraying, and cleaning equipment. Goggles, rubber gloves, and respirators or masks are standard equipment when handling pesticides. Review the sprayer operator's manual and chemical labels for recommended procedures regarding safe use of equipment and chemicals.

Acknowledgment

The author thanks Drs. John Fulton and Dewey Mann, Department of Food, Agricultural and Biological Engineering; and Mary Griffith, Agriculture and Natural Resources Extension Educator, Ohio State University Extension, for reviewing this publication and for their editorial contributions.