Colorado State University

Extension

Sprayer Calibration Fundamentals

Fact Sheet No. **5.003** Farm and Ranch Series | **Equipment**

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Quick Facts

- Inaccurate pesticide application rates, spray patterns and droplet size can lead to the movement of pesticides from the targeted area and reduce pesticide effectiveness.
- The first step in sprayer calibration is to determine the correct nozzle type and size.
- Nozzle material is important in reducing inaccurate applications due to nozzle wear.

Due to timeliness and effectiveness, chemical pesticide application has become a leading method of weed and insect control in U.S. agricultural production. The continued use of pesticides in the agricultural industry has led to concerns of chemical trespassing by groundwater contamination or drift.

Inaccurate pesticide application rates, spray patterns and droplet size can lead to pesticide movement from the targeted area and reduce the effectiveness of the pesticide. A recent study in Nebraska revealed that two-thirds of the applicators were applying pesticides improperly (application rate errors greater than 5 percent). A similar study conducted in North Dakota indicated that 60 percent of tested sprayers had calibration errors greater than 10 percent. Although inaccurate tank mixing causes some of these errors, a majority of the problems result from improper spray equipment calibration and worn nozzles.

Nozzle Selection

The first step in sprayer calibration is to determine the correct nozzle type and size (flow rate). Flat-fan nozzles are used for broadcast spraying of most herbicides and some insecticides where a medium droplet size is needed. Flat-fan nozzles are used for banding herbicides. Flooding type and full cone nozzles used for pre-plant herbicides produce drift-resistant large droplets, and wide nozzle spacing can be used. Hollow cone nozzles produce smaller droplets and are used to apply insecticides and contact herbicides that need to penetrate the canopy.

Inaccurate applications can be due to nozzle wear. Therefore it is important to select the correct nozzle material. Wear-resistant materials such as tungsten, carbide, ceramic and hardened stainless steel help nozzles maintain a constant flow rate after a long period of use. Nozzles made from less durable materials (plastic, brass) demonstrate increased flow rates after only a short period of spraying. For example, after 50 hours of spraying, a brass nozzle can have an increased flow rate of 10 to 15 percent, whereas a hardened stainless steel nozzle will increase only about 2 percent. The increased flow rates result from an increased nozzle orifice area. The added cost to purchase a more durable nozzle can pay for itself many times over by reducing the overapplication that results from nozzle wear.

Nozzle size depends on the desired application rate, ground speed and nozzle spacing. For each nozzle type and spray angle, the manufacturer recommends spray height and nozzle spacing. Nozzle spacings of 20 and 30 inches are most common. The desired flow rate from the nozzle can be determined from the following equation:

$$GPM = (GPA \times MPH \times w) / 5940$$

where:

GPM = the nozzle flow rate in gallons per minute,

GPA = the application rate in gallons per acre,

MPH = the ground speed of the sprayer in miles per hour (MPH = (ft/min) / 88), and w = the nozzle spacing in inches for broadcast spraying.

Calibration Procedure

Spray Rig Preparation

1. Thoroughly clean the spray rig. Check for signs of rust, leaks or other problems.
2. Determine the gallons needed per acre based on the recommended rate from the pesticide label, tank size, pesticide container size, and rate of pesticide application per acre.

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3. Calculate a rough estimate of nozzle application rates based on the planned application speed and boom pressure.
4. Check all nozzles on the spray boom for signs of wear and nozzle size. Replace worn nozzles and nozzles of the wrong size for the desired application.
5. Half-fill the spray tank with water and go to the prepared field.

One Way to Calibrate a Sprayer

1. Measure the ground speed of the rig with the sprayer implement in place. (Average the travel time of the tractor in seconds over 300 feet in the field for two separate passes.)
2. Calculate the ground speed.
3. Measure the distance in inches between spray nozzles on the boom.
4. Calculate the desired nozzle output (ounces or gallons).
5. Catch one minute's worth of water from one or two nozzles at the operating pressure.
6. Adjust the pump pressure or ground speed until the desired output is reached.
7. Calculate the acreage covered on one tank of spray mixture.
8. Finish filling the spray tank with pesticide and carrier (usually water). Apply about one-half tankful of spray and determine if the correct amount of acreage has been covered.
9. Continue spray application; recalibrate if the first half tankful didn't cover the correct acreage.

Example

The field is prepared and spray tanks, booms and nozzles have been cleaned and checked. The pesticide label recommends that 1 quart per acre of chemical and a minimum application of 10 gallons of mixture per acre be applied. The pesticide comes in 2 ½ gallon containers; the spray tank holds 350 gallons. Three hundred gallons can be applied before refilling.

In this situation, applying pesticide to 30 acres with one tankful would comply with the label. Solid-applied herbicides generally work better with larger volumes of spray mixture. One full container of chemical will cover 10 acres. If 15 gallons of carrier per acre are applied, the applicator would get 20 acres per refill and use two containers of pesticides.

The tractor with spray rig is set as if spraying the first 300-foot pass in 42.5 seconds. The second pass is a bit faster, at 42.7 seconds. The average time is 42.6 seconds.

MPH = 300 ft / (1.47 x 42.6 sec)
= 4.8 MPH

Spray nozzles are spaced at 30 inches. Using the formula acreage output rates to nozzle output, application will be about 0.364 gallons per minute per nozzle.

GPM = (15 GPA x 4.8 MPH x 30 inches) / 5940 = 0.364 GPM

Experience shows that the pump can handle this volume and nozzles are rated for this application. Field application is now ready.

The nozzle output now can be checked at the field's edge. Once adjustments are made and each nozzle checks within 5 percent of the desired output, fill the tank with pesticide and water.

Ten acres should be covered by the time the half-tank level is reached using the example above.

A standard nozzle with a flow rate of 0.4 gallons per minute at 40 psi is easy to obtain. The 15-gallon per acre application rate can be obtained by operating the sprayer at the recommended 40 psi and a higher ground speed.

MPH = (GPM x 5940) /(GPA x w)
= (0.4 GPM x 5940) / (15 GPA x 30 in)
= 5.3 MPH

Or the ground speed can be kept constant at 4.8 miles per hour, and the nozzle pressure reduced using the following relationship.

Pressure new / pressure rated = (GPM desired / GPM rated)^2 =
Pressure new / 40 psi = (.364 GPM / .4 GPM)^2

The new pressure is 33 psi. Use small adjustments in pressure to obtain the desired nozzle flow rate within the recommended operating pressure. Operating a nozzle at excessively high pressures will produce small spray droplets susceptible to drift. Operating at excessively low pressures produces larger, less-effective spray droplets and poor spray pattern uniformity down the length of the boom.

If calibrating with water and spraying solutions that are heavier or lighter than water (8.3 pounds per gallon), use the conversion factors in Table 1.

Table 1: Spraying solution conversion factors.

Weight of solution (per gallon)	Specific gravity	Conversion factors
7.0 lbs	.84	.92
8.0 lbs	.96	.98
8.3 lbs*	1.00	1.00
9.0 lbs	1.08	1.04
10.0 lbs	1.20	1.10
11.0 lbs	1.32	1.15
12.0 lbs	1.44	1.20
14.0 lbs	1.68	1.30

*Suitable for most water-soluble pesticides.

In the above example, to obtain a nozzle flow rate of 0.364 GPM with a solution that weighs 10 pounds per gallon, the nozzle should produce 0.364 GPM x 1.10 or about 0.40 GPM when spraying water.

Spray System Checks

After all the adjustments are made, fill the sprayer with water and measure the nozzle flow rates by catching the nozzle output for 1 minute. Divide the number of ounces by 128 (128 ounces in a gallon) to obtain the flow rate in gallons per minute. For example, 67 ounces caught in 1 minute produces a flow rate of 67/128 or 0.52 GPM. Another method of measuring nozzle flow rates is with a spray tip tester. Maintaining the desired application rate is essential. Over-application results in wasted pesticide, potential groundwater contamination, and possible crop injury. Under-application can produce ineffective pest control.

Erroneous flow rates can result from damaged, worn or plugged nozzles or strainers, and spray hose restrictions between the pressure gauge and the nozzle. Clean nozzles with a toothbrush, not a pocket knife. Never blow out a nozzle with the mouth.

Check the pressure along the length of the boom. If a large pressure difference is found, look for restrictions or install a larger diameter spray hose (see Table 2). An accurate pressure gauge is worth the extra cost.

Table 2: Pressure drop through various hose sizes.

Flow in GPM	Pressure drop in PSI (in 10-foot length) without couplings				
	1/4" I.D.	3/8" I.D.	1/2" I.D.	3/4" I.D.	1" I.D.
0.5	1.4	.2			
1.0		.7			
1.5		1.4	.4		
2.0		2.4	.6		
2.5		3.4	.9		
3.0			1.2		
4.0			2.0		
5.0			2.9	.4	
6.0			4.0	.6	
8.0				.9	.3
10.0				1.4	.4

Field Checking

Conduct field calibration when spraying the pesticide. Start with the tank full of solution, spray a known distance in the field (at least 3,000 feet) and determine the number of gallons needed to refill the tank. Determine the application rate (GPA) with the following formula.

GPA =(gallons sprayed x 43,560) /(Boom width (ft.) x distance (ft.))

Spray Distribution Uniformity

Spray distribution uniformity is important for broadcast spraying. Uniform spray coverage eliminates weed streaking and crop injury. Concentrations up to four times the recommended amount can result from non-uniform applications. To obtain even coverage, make sure all the nozzles are the same and are equally spaced along the boom. Check each nozzle to make sure the flow rates are correct. Replace nozzles if the flow rates are 10 percent or more in error. The boom height should be adjusted to the recommended height (Table 3). Spray boom bounce should be minimized with support members.

Table 3: Nozzle height (inches) for flat-fan nozzles.

Spray angle (degree)	20-inch spacing	30-inch spacing
65	21-23	32-34
73	20-21	27-29
80	17-19	25-27
110	10-12	14-18

Check spray uniformity by spraying water on a concrete surface and observing the amount of streaking that occurs when the water dries. Spray patterns that result in excessive accumulation below the nozzle are produced by:

1. nozzle wear,
2. low boom height,
3. low operating pressure, and
4. large nozzle spacing.

Irregular spray patterns result from damaged nozzle tips, mismatched nozzles and uneven booms.

Pesticide drift is a major concern. In addition to reducing effectiveness, pesticide drift can damage non-target areas. One method to decrease drift is to use a low volatile formulation that is less likely to volatize and drift.

Pesticide drift also can be controlled by reducing the number of small droplets emitted from the sprayer. Nozzle type, angle and orientation, boom height, and operating pressure can influence the production of driftable drops. A droplet of 100 microns in diameter can drift about 50 feet in a 3 mph breeze; a 10- micron droplet can drift 3,000 feet. Spray thickeners can reduce drift, as can spraying at low temperatures and high humidity.

Useful Formulas and Equivalents

1 acre = 43,560 square feet

1 gallon = 128 fluid ounces

1 pint = 16 fluid ounces

1 pound = 16 ounces of weight (16 fluid ounces of water at 39 degrees Fahrenheit weighs 1 pound)

Gallons per acre = (5,940 x gallons/minute/nozzle) / (MPH x nozzle spacing)

Gallons per minute per nozzle = (gallons/acre x MPH x nozzle spacing) / 5,940

Ounces per minute per nozzle = (gallons/acre x MPH x nozzle spacing x 32) / 1,485

Miles per hour = distance travelled (ft) / (88 x minutes) = distance travelled (ft) / (.47 x seconds)