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Calibrating Field Sprayers

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Pesticides are most cost-effective and perform optimally when applied at labeled rates. Too much pesticide can injure crops; too little can give inadequate or unreliable control. Careful calibration is essential to proper sprayer operation, and the economic return on the small investment of time required can be substantial.

The volume of spray mix applied per acre by a sprayer depends on (1) nozzle flow rate, (2) width sprayed and (3) travel speed of the sprayer.

Before calibrating a sprayer, select the nozzles to be used. Nozzles should be matched and replaced as a set except under unusual circumstances. Even new nozzles should be checked for proper operation.

The following example provides a framework for working through the calculations necessary for nozzle selection and sprayer calibration. Consider a tractor-mounted sprayer with two 200-gallon saddle tanks that apply herbicide during planting. The spray boom and nozzles will broadcast spray the width planted with a six-row (30-inch row spacing) planter. The selected pesticide is a tank mix of alachlor plus imazaquin for preemergence weed control in soybeans. In the examples that follow, calculations for nozzle selection and calibration procedures are based on this setup. A worksheet is included on page 4.

Nozzle selection

Step 1. Select the sprayer application rate. A recommended range of sprayer application rates, in gallons per acre, is given on the pesticide label. From that range, choose the rate that is compatible with your spraying equipment.

> ***Example:*** From the recommended range of application rates on the label of both herbicide containers, you select the rate of 20 gallons per acre because that rate is compatible with the nozzles that you already have.

Step 2. Select the field speed. Choose a speed that can be maintained at all times. A 10 percent reduction in speed will result in a similar overapplication of pesticides. Where speed must be reduced for a short period at the end of a pass through the field or in other situations, a small reduction in engine speed is preferable to selecting a lower gear. Reducing the engine speed causes the nozzle flow rate as well as the travel speed to decrease, although not proportionately. If slowing is frequently necessary, calibrate the sprayer for the slower speed.

> ***Example:*** You plant soybeans at 6 mph on a certain tract of land. Since you intend to spray during planting, you will calibrate your sprayer for 6 mph.

Step 3. Determine the width sprayed by each nozzle. The width sprayed by each nozzle on a broadcast spray boom is the distance between nozzles. If a sprayer has nozzles spaced every 20 inches on the boom, the width sprayed by each nozzle is 20 inches. If a sprayer has several nozzles that will be used to spray each row, such as sprayers used to apply insecticides to row crops, then the width sprayed by each nozzle is the distance between rows divided by the number of nozzles used to spray each row. If the sprayer is a band sprayer and the labeled rate applies to the actual area sprayed, the width is the width of the band. If the sprayer is a band sprayer and the labeled rate applies to the total area covered, the width is the spacing between rows.

> ***Broadcast example:*** A sprayer has nozzles that broadcast spray in front of the entire width of the planter. The nozzles are 15 inches apart. Hence, the width sprayed by each nozzle is the nozzle spacing — in this case, 15 inches.

> ***Row unit example:*** A sprayer has one nozzle that will be above the row and two that will be between rows. The rows are 30 inches apart. Each row will be sprayed with three nozzles. The effective width sprayed by each nozzle is 10 inches (30 inches/row divided by 3 nozzles/row = 10 inches/nozzle).

> ***Applied area band example:*** A sprayer is to apply a 10-inch band over the row or between rows. The rows are 30 inches apart. The labeled rate is stated for the actual sprayed area. The width accounted for by the nozzle is 10 inches.

> ***Total area band example:*** A sprayer is to apply a 10-inch band over the row or between rows. The rows are 30 inches apart. The labeled rate is stated for the total area covered by the unit. The width accounted for by the nozzle is 30 inches.

Step 4. Determine the nozzle flow rate. The nozzle flow rate can be calculated using Equation 1.

Equation 1. Flow rate

$$GPM = \frac{GPA \times S \times W}{5{,}940}$$

where
- GPM = nozzle flow rate (gallons per minute)
- GPA = sprayer application rate (gallons per acre), as selected in Step 1.
- S = speed (miles per hour), as selected in Step 2.
- W = width sprayed by each nozzle (inches), as determined in Step 3.
- 5,940 = a constant for conversion of units

Example:
- GPA = 20 gal/acre as selected in Step 1.
- S = 6 mph as selected in Step 2.
- W = 15 inches as determined in Step 3

therefore,

$$GPM = \frac{20 \times 6 \times 15}{5{,}940}$$

$$= 0.303 \text{ gal/min}$$

Step 5. Select nozzles. Use the nozzle manufacturer's catalog to select a nozzle that will have a flow rate (Step 4) within the range recommended on the pesticide label.

Example: You want to use a flat fan nozzle to apply the pesticides. The nozzle manufacturer's catalog lists the nozzle number, pressure and flow rate. You don't find the exact value calculated in Step 4 (0.303 gal/min), so you select a nozzle with a flow rate range that includes 0.303. Table 1 is an example from a typical nozzle catalog. You decide to use an 8003 nozzle because you observe that 0.303 is within the range of flow rates shown for that nozzle.

Table 1. Pressure and flow rates for some common flat-fan nozzles.

Nozzle	Pressure (psi)	Flow rate (gal/min)
8002	30	0.17
	40	0.20
	50	0.22
	60	0.24
8003	30	0.26
	40	0.30
	50	0.34
	60	0.37
8004	30	0.35
	40	0.40
	50	0.45
	60	0.49

Calibration

Step 1. Check general sprayer operation. Fill the supply tank with clean water and operate the pump. Check for leaks, proper operation of the pressure gauge, and clogged or worn nozzles. Nozzle wear and clogged nozzles cannot usually be detected visually. Refer to calibration Step 4 for procedures to measure nozzle performance. Clogged nozzles can be cleaned with a soft brush. Nozzles should generally be replaced as a set unless mechanical damage to a single nozzle occurs in an otherwise good set. Flow rate increases with the use of a nozzle. Wear is greater for pesticides in suspension than for soluble pesticides. Wear rates are also higher for low-capacity nozzles and nozzles operated at high pressures. Nozzle material has the greatest effect on nozzle life (Table 2). Brass nozzles should probably be replaced seasonally or more often, while hardened stainless steel nozzles may last for the lifetime of some sprayers.

Table 2. Lifetime wear for typical nozzle materials

Nozzle material	Nozzle life
Brass	Poor
Nylon	Fair
Stainless steel	Good
Plastic	Good
Hardened stainless steel	Excellent

Step 2. Check travel speed. Lay out a known distance in a field with representative soil conditions. Calibration of speed is dependent on soil types and conditions. Use a distance of 176 feet for speeds up to 8 mph and 352 feet for speeds greater than 8 mph. Use a loaded sprayer and operate the sprayer or tractor with the throttle setting and gear selection that you want to use throughout the spraying operation. Measure, once in each direction, the time to travel the known distance. Determine the average of the times and use Equation 2 to determine the travel speed. Check your calculation using the example below.

Equation 2. Travel speed

$$S = \frac{D \times 60}{T \times 88}$$

where
- S = travel speed (miles per hour)
- D = distance (feet)
- T = travel time (seconds)
- 60 = a constant (seconds per minute)
- 88 = a constant (miles per hour in feet per minute)

Note the selected gear and throttle setting used during the speed check. Record the tachometer reading for use in setting the throttle during operation.

Example: You place two stakes 176 feet apart in the field. You find it takes 19.5 seconds to drive one way and 20.5 seconds to drive the other way, an average of 20 seconds. Calculate the travel speed using Equation 2:

$$S = \frac{176 \times 60}{20 \times 88} = 6 \text{ mph}$$

It is normal for the tachometer or speed display to indicate speeds greater than 6 mph due to wheel slip. Wheel slip can be substantial under heavy drawbar loads.

Step 3. Calculate the spray volume and determine proper operating pressure. Multiply the nozzle flow rate in gallons per minute by 128 oz / gal to get ounces per minute.

Example: Multiplying the nozzle flow rate of 0.303 gal/min by 128 oz/gal, you find that the rate is 39 oz/min. You desire your calibration to be within 5 percent of the target rate; therefore, multiplying 39 oz/min by 0.05, you find that you need to be within 2 ounces of the target rate of 39 oz/min. You should collect a volume of spray no less than 37 ounces and no greater than 41 ounces in 1 minute.

Use the manufacturer's information to estimate the operating pressure required to achieve the desired flow rate for the selected nozzle.

Example: You checked the nozzle catalog and found that the approximate pressure needed to obtain a flow rate of 0.303 is a little more than 40 psi.

Step 4. Measure nozzle flow rate. To perform the following test, the sprayer must be operated at constant pressure. Use a graduated container large enough to hold the spray produced by one nozzle in more than 1 minute at the selected operating pressure. Place the empty container under a nozzle and collect all of the spray for exactly 1 minute. Place the container on a level surface and record the volume of spray to the nearest ounce. Repeat for each nozzle, making a list of the output. Compare the nozzle outputs recorded on the list. Nozzles that have an unusually large flow rate should be replaced. Nozzles that have unusually small flow rates may only need to be cleaned with a soft brush. Hard tools will damage nozzles. Even a toothpick may damage some tips. Nozzles cannot be repaired.

Example: You use a plastic container that is graduated in ounces to measure the output from a nozzle. You start the sprayer and adjust the pressure so that the gauge reads approximately 40 psi. You collect the output from a nozzle for 1 minute.

In this example, nozzles that provide more than 41 ounces during the test may be worn enough to be replaced. Nozzles that provide less than 37 ounces may be plugged and should be cleaned with a soft brush.

Step 5. Determine the rate of spray that will actually be applied per acre. Add the rates for all nozzles and divide by the number of nozzles. If the average is higher by 5 percent, expect to cover *approximately* 5 percent fewer acres. If the material is supposed to be enough to cover 20 acres, you will lose the capacity to cover one of those acres (0.05 × 20 acres = 1 acre).

Step 6. Adjust pressure to apply the correct rates. Reduce pressure by about 10 percent to correct for flow rates that are too large by 5 percent. The relationship between pressure and flow rate is not a straight line. Pressure must increase by four times to increase flow rate by a factor of two (100 percent) as shown in Table 3. A different set of nozzles should be selected if a large change in flow rate is required.

Table 3. Multiplication factors for adjusting nozzle flow rate.

To *increase* flow rate by (Percent)	Multiply pressure by	To *decrease* flow rate by (Percent)	Multiply pressure by
5	1.10	5	0.90
10	1.21	10	0.81
15	1.32	15	0.72
20	1.44	20	0.64
30	1.69	25	0.56
40	1.96	30	0.49
50	2.25	35	0.42
60	2.56	40	0.36
75	3.06	45	0.30
100	4.00	50	0.25
2 x flow	*4 x pressure*	*flow/2*	*pressure/4*

Example: You collect output from all nozzles at an initial pressure of 40 psi. The average volume of spray collected in 1 minute just exceeds 41 ounces, which is more than 5 percent above the target rate. Using the multiplication factor for decreasing flow rate by 5 percent (0.90) from Table 3, you determine that the new operating pressure should be 36 psi (40 psi × 0.90) — a decrease of 10 percent, or 4 psi.

Repeat steps 5 and 6 until the recorded flow rate is within 5 percent of the desired rate. It is not necessary to collect spray from every nozzle as you repeat the calibration. Using the list created earlier, select a nozzle that has a flow rate similar to the average rate for all nozzles. If the results of a change in pressure do not appear to be correct, repeat the calibration using all of the nozzles.

The cost of misapplied pesticides due to decreased nozzle performance comes in many forms. Crop plants that receive too much herbicide can be damaged. Weed plants that receive too little herbicide may not be controlled. A 5 percent increase in application rates for pesticide treatments that cost $40 per acre amounts to extra costs of $2,000 on 1,000 acres. The cost of new nozzles is small in comparison.

Step 7. Recheck the nozzle output. Check nozzle flow rate frequently. Adjust the pressure, when necessary, to compensate for changes in flow rate caused by nozzle wear. Spray tip testers that attach to the tip may be useful for spot checking nozzle flow rates on some nozzles. When using spray tip testers, periodically compare the flow rate of the tester to that calculated by catching a volume of spray.

Note: This publication replaces two former publications:
G 1270, *Sprayer Calibration: Broadcast Sprayers*
G 1271, *Sprayer Calibration: Band Sprayers*

Sprayer Calibration Worksheet

(retain for your records)

Sprayer and tractor identification: Sprayer ______________________ Tractor ______________________

Nozzle selection: Sprayer application rate ________ Field speed ________ Nozzle spray width __________

Calculate: Nozzle flow rate (step 4)

Nozzle type __________________ Recommended pressure ________

Calibration: Gear selection ________________ Engine speed __________________

Calculate: Travel speed (step 2)

Calculate spray volume: Minutes to collect spray (one minute recommended) ____________________

Ounces to collect = gallons per minute (above) $\times$ 128 $\times$ minutes of spray collected

5 percent error = ounces to collect $\times$0.05

Minimum spray to collect = ounces to collect $-$ error

Maximum spray to collect = ounces to collect $+$ error

Sprayer test procedure:

Operating pressure ________________ psi @ ________________ engine speed

Nozzle	Spray volume	Nozzle	Spray volume	Nozzle	Spray volume	Nozzle	Spray volume
______	____________	______	____________	______	____________	______	____________
______	____________	______	____________	______	____________	______	____________
______	____________	______	____________	______	____________	______	____________
______	____________	______	____________	______	____________	______	____________
______	____________	______	____________	______	____________	______	____________
______	____________	______	____________	______	____________	______	____________

Total spray volume: (add spray volumes in all columns) ______________

Average spray volume = Total spray volume $\div$ number of nozzles

Calculate percent underapplication:

Difference = desired spray volume $-$ actual or average spray volume

Percent underapplication = 100 $\times$ difference $\div$ desired spray volume

Increase flow rate (choose multiplication factor from left column of Table 3)

Calculate percent overpplication:

Difference = actual or average spray volume $-$ desired spray volume

Percent underapplication = 100 $\times$ difference $\div$ desired spray volume

Increase flow rate (choose multiplication factor from right column of Table 3)

Previous operating pressure ______________

Calculate: New operating pressure = previous operating pressure $\times$ multiplication factor from Table 3

Repeat calibration until spray volume is within 5 percent.

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