Calibrating a Sprayer with the Ounce Collection Method

K·STATE
Research and Extension

Application Technology Series

John W. Slocombe, *extension agricultural engineer, machinery systems, Kansas State University*

Rising chemical costs and new low-rate chemicals are making accurate field applications more important than ever before. Proper sprayer calibration must be a primary management consideration of farmers and custom applicators. Since most pesticides are applied with hydraulic sprayers, operators should also know proper application methods, chemical effects on equipment, and correct cleaning and storage methods for hydraulic sprayers.

Proper sprayer application depends on the combination of eight basic properties:

- sprayer design
- nozzle type
- boom height
- boom pressure
- agitation
- chemical dilution
- flow rate
- ground speed

Chemicals will be applied correctly when these eight components are used in the right combination, and chemicals have been properly mixed. Properly applied pesticides are expected to result in a profit. Improper application can result in wasted chemicals; marginal weed, insect, or disease control; excessive carryover; groundwater contamination; and crop damage. Inaccurate application is usually costly and reduces income.

Preseason visual checks of existing equipment are not adequate for accurate application, and new equipment should also be calibrated. In several surveys, only one of three applicators was applying within +/- 5 percent of estimated rate. Check all nozzles for correct flow rates and uniform application, and calibrate the sprayer. Manufacturers' catalogs are guidelines, but fine-tuning a sprayer is the operator's responsibility. Sprayers should be calibrated every time a different pesticide is applied. In addition, a sprayer should be recalibrated at least every other day when in continuous use. Since these checks may have to be performed often, evaluating a sprayer quickly and without excessive investment or calculation is essential. There are a number of calibration techniques. The following section outlines a method for quick sprayer calibration.

Determining Gallons per Acre (gpa)

The purpose of any calibration method is to determine the number of gallons of solution being applied per acre. Subsequently, the gallons of solution applied per acre can be used to determine the quantity of active ingredients to add in the spray tank. The following method requires a stopwatch, a container for collection, a tape measure, marking flags, and a scale or container graduated in ounces. The procedure is as follows:

Step 1. Select the nozzle spacing distance on the broadcast boom shown in Table 1. When using a directed or banding rig, use the row spacing. Measure the correct field application distance in a level field. The distance measurement may be permanently marked. The travel area should be typical of the surface and soil conditions of the area to be sprayed. Many tractors and sprayers gain or lose more than 10 percent of desired travel speed while moving up and down slopes. If field variations are wide, several areas may be needed. Remember, this traveled distance gives a clue to the actual speed the sprayer is going under field conditions; therefore, the measured distance and timing must be exact.

Step 2. Drive and time the travel distance of the sprayer in seconds (Figure 1) at the throttle setting and load that normally occurs during spraying

Step 2

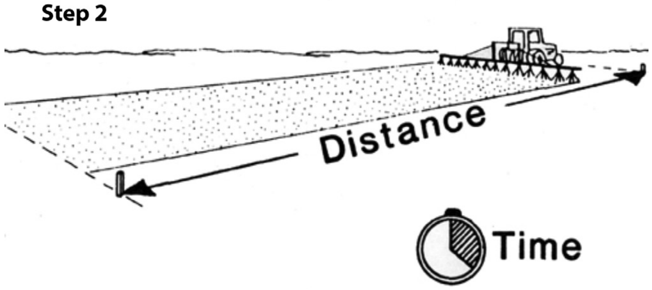

Figure 1. Step 2: Measure the appropriate field length for the nozzle spacing, then measure the time in seconds to run the course.

(spray tank should be ½ to ⅔ full) over the marked area. Engage the incorporation equipment (disk, planter, etc.) or other devices used while spraying. Do not change the gear or throttle setting after you have chosen a spraying speed. A change in ground speed changes the sprayer application rate and requires recalibration.

Step 3. While in a stationary position, bring the power unit to the proper throttle setting and sprayer to the correct boom pressure used in step 2. Catch the nozzle discharge for the time recorded in Step 2. Measure the discharge in ounces (Figure 2) with a graduated container or scale. If more than one nozzle per row is used (direct, insecticide, or fungicide rigs), catch the discharge of all nozzles within the row spacing selected in step 1. Then combine the amount of discharge from all nozzles spraying in that row.

Remember, from a safety point of view, **the collection of discharge should be done using clean water only.** Even while collecting water, use the proper personal safety clothing and protection.

Step 4. The total discharge measured in ounces is equal to gallons per acre (gpa) applied. Since this calibration was based on water, conversion factors (Table 2) must be used when spraying solutions that are heavier or lighter than water. Multiply the observed rates by the conversion factors to attain accurate rates using the spray solutions.

Example of Ounce Calibration. Suppose a sprayer was set up with 30-inch nozzle spacing. *Step 1.* Using Table 1, 136 feet was marked off and the sprayer was driven through and timed. *Step 2.* The time recorded was 21 seconds. According to Table 1, the travel speed was about 4.5 mph.

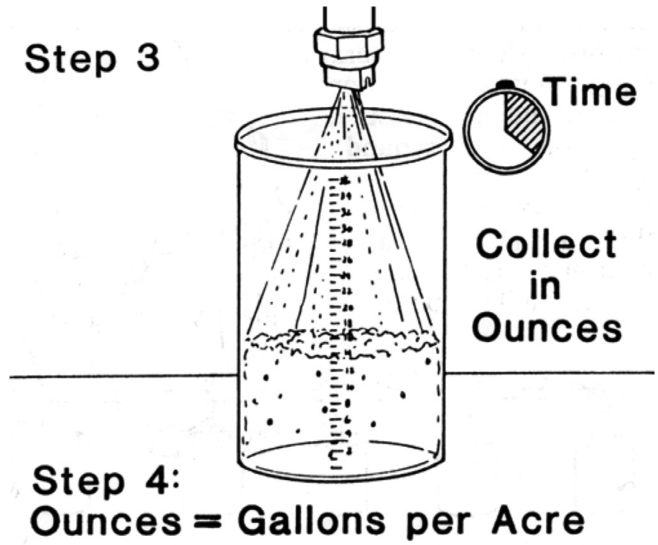

Figure 2. In stationary position and proper boom pressure, measure the output over the same time period to make the run. The number of ounces collected is equal to the gallons per acre.

Step 3. In a stationary position, the sprayer was brought to the proper pressure. A nozzle was collected for 21 seconds as found in Step 2. The discharge was measured to be 15 fluid ounces. *Step 4.* The calibration was 15 gallons per acre. Several nozzles should be measured and averaged from different sections on the boom (i.e. left, right, and center) for a more reliable measurement.

Suppose the actual carrier will be 28 percent fertilizer and not water. The carrier rate should be adjusted. Using Table 2, the carrier rate would be: [15 gpa × .885 (Table 2)] = 13.3 gpa. This would be the value used to determine the proper amount of active ingredient to add to the spray tank.

Calibrate Frequently. The ounce calibration method describes a procedure using minimal calculations in order to evaluate a hydraulic sprayer. Most farmers use the "known area" calibration method. This method requires the operator to know a given area and determine the number of gallons of liquid applied to that area by the sprayer. The gallons per acre can be calculated by dividing the number of gallons applied by the known acres covered. The method is a useful field check but should not be the primary method because an error of misapplication can occur before it can be detected.

Table 1. Calibration distances and speeds for varying nozzle or row spacing.

Nozzle or Row Spacing (in)	Calibra-tion Distance (ft)	Time in Seconds for Various Ground Speeds (mph)*							
		3.0 mph	**3.5 mph**	**4.0 mph**	**4.5 mph**	**5.0 mph**	**6.0 mph**	**7.0 mph**	**8.0 mph**
40	102	23.2	19.9	17.4	15.5	14.0	12.6	9.9	8.7
38	107	24.3	20.8	18.2	16.2	14.6	12.2	10.4	9.1
36	113	25.7	22.0	19.3	17.1	15.4	12.8	11.0	9.6
34	120	27.3	23.4	20.5	18.2	16.4	13.6	11.7	10.2
32	127	28.9	24.7	21.6	19.2	17.3	14.4	12.4	10.8
30	136	30.9	26.5	23.2	20.6	18.5	15.5	13.2	11.6
28	146	33.2	28.4	24.9	22.1	19.9	16.6	14.2	12.4
24	170	38.6	33.1	29.0	25.8	23.2	19.3	16.6	14.5
22	185	42.0	36.0	31.5	28.0	25.2	21.0	18.0	15.8
20	204	46.4	39.7	34.8	30.9	27.8	23.2	19.9	17.4
18	227	51.6	44.2	38.7	34.4	31.0	25.8	22.1	19.3
16	255	58.0	49.7	43.5	38.6	34.8	29.0	24.8	21.7
14	291	66.1	56.7	49.6	44.1	39.7	33.1	28.3	24.8
* 1 mph = 88 feet per minute									
Note: For times less than 20 seconds (shaded area) improved accuracy can be attained by doubling the collection time (Step 3) and dividing the output collected by two.									

Table 2. Conversion factors for solutions with densities different than water.

Density of Solution (lb/gal)	Specific Gravity	Conversion Factors
7.0	.84	1.092
8.0	.96	1.021
8.34 water	1.00	1.000
9.0	1.08	0.963
10.0	1.20	0.913
10.65 28% nitrogen solution	1.28	0.885
11.0 7-27-7 fertilizer	1.32	0.871
11.06 32% nitrogen solution	1.33	0.868
11.40 10-34-0 fertilizer	1.37	0.855
11.50 12-0-26 fertilizer	1.38	0.852
11.60 11-37-0 fertilizer	1.43	0.848
12.0	1.44	0.834
14.0	1.68	0.772

Table 3. Conversion factor to convert broadcast rate (gallons per total acre) to band rate (gallons per treated acre).

Band width (in)	Row Spacing (in)			
	20	**30**	**36**	**40**
8	2.5	3.8	4.5	5.0
10	2.0	3.0	3.6	4.0
11	1.8	2.7	3.3	3.6
12	1.6	2.5	3.0	3.3
13	1.5	2.3	2.8	3.1
14	1.4	2.1	2.6	2.9
15	1.3	2.0	2.4	2.7
16	1.2	1.9	2.3	2.5

Band Applicator Calibration

The same calibration methods can be used to calibrate band applicators and broadcast spraying. The only difference is the amount of area being covered. Total acres refer to the entire acreage in the field. This would include the sprayed band and the area between the bands. A treated acre refers only to the treated area in the band. The spray that would be discharged by the broadcast rate is concentrated in a narrow band by the ratio of row spacing to band width (Table 3 on previous page). In band spraying, the row spacing and the nozzle spacing are the same. After performing steps 1 through 4 of the above procedure, multiply the answer by the appropriate conversion factor to attain band rate.

Unless otherwise specified, chemical application rates are given on a broadcast basis. For band applications, the rate per treated area is the same as the broadcast rate, but the total amount of pesticide used on a field is less because only a portion of the field is treated.

Nozzle Discharge and Uniformity Check

Good nozzle condition is essential for uniform application. Observe the spray pattern from each nozzle. If the spray pattern is not uniform from visual observations, large output variations exist. Often, poor spray patterns are due to clogged nozzles and strainer components. To clean a metal nozzle or strainer, use an old toothbrush or a wooden toothpick. For plastic-tip nozzles, use only a nylon (rather than brass fibers) toothbrush (special nozzle cleaning brushes are available). Never use a metal object when cleaning a nozzle or strainer.

Check nozzle discharge uniformity (Figure 3) by repeating steps 3 and 4 above for all nozzles.

If variation of output is not within 10 percent of the average output of the nozzles, replace all the nozzles. After adjustment or correction, recalibrate. To calculate the gallons per minute (gpm) discharge of a nozzle, use:

gpm = ounces collected × 0.47 ÷ time (in seconds)

The flow rate (gpm) can be adjusted slightly by changing pressure. However, to double the output, the pressure will need to be increased four times. High pressures (greater than 45 psi) may exert excessive strain on sprayer components, increase wear on the nozzles, and produce drift-susceptible spray. Low pressures (lower than 10 psi) will not develop a full-width spray pattern for each nozzle, and coverage may not be adequate for contact pesticides. If more discharge is required, the best methods are to increase the nozzle size or to slow down the travel speed. Remember the limits because most nozzles perform best over a limited pressure range.

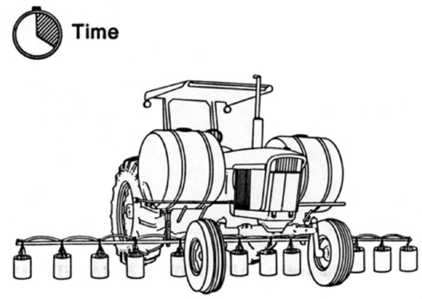

Figure 3. Check the discharge from each nozzle across the boom.

The relationship between gallons per acre (gpa) and nozzle output in gallons per minute (gpm) can be determined by using the sprayer speed in miles per hour (mph) and spray width in inches (w) using the following equation:

gpa = (5,940 × gpm) ÷ (mph × w)

where: w = nozzle spacing in broadcast or band spraying, spray swath of boomless spraying, or row width of directed rigs.

Do not mix nozzles of different materials, types, discharge angles, or gallon capacity on the same sprayer. Mixing nozzles produces uneven spray patterns. Select the correct type of nozzle spray pattern for the intended job. Know the specific use of a nozzle tip. One nozzle type will not meet all spraying needs, so plan ahead.

Another factor influencing spray uniformity is boom height. Boom height controls the amount of nozzle pattern overlap. Best performance of a broadcast sprayer is when the nozzle spacing, height, and angle provide for 100 percent overlap at the target height. Booms should be relatively rigid in all directions. Swinging back and forth or up and down is undesirable. Gauge wheels mounted near the boom ends should help maintain a uniform boom height.

The primary way to check uniformity at the ground surface or target height of broadcast and banded rigs is the use of corrugated spray tables or spray tapes. Due to the expense, these devices are probably not practical for individual ownership. However, a quick check of uniformity can be performed by spraying over a hot slab of concrete and watching the dry patterns. Areas that dry faster may indicate where proper overlap has not been achieved.

Ground Speed Check

A survey of field sprayers indicated 65 percent of the operators had errors of greater than 5 percent in estimated travel speed. Step 2 of the described sprayer evaluation method provides a clue to the actual speed the sprayer was traveling under field conditions. Accurate application requires that the operator know exactly how fast the sprayer moves over the ground surface. Because of wheel slippage and rough surface conditions, the actual rig velocity is often different from the tachometer and speedometer readings. For a more accurate measurement of travel speed, mark off a distance of 220 feet. Drive and time the operation as in Step 2. The speed is calculated as:

mph = 150 ÷ seconds timed

Pump Pressure Check

The pump output should have at least 20 percent more capacity than the largest volume required by the nozzles. A pump with reserve capacity allows for proper agitation and deliver the necessary volume as the pump wears. The pump should be evaluated if the system is not receiving adequate pressure. In order to check pump capacity, disconnect the outlet side of the pump and put the hose in a 55 gallon drum. Run the pump at the throttle setting normally used during spraying. Measure the time (in minutes) required to fill the drum. Calculate the pump capacity by dividing 55 gallons by the minutes measured. If the pump's capacity is too small or excessively worn, replace it.

Inadequate hose size could also cause pressure reductions. If the hose size is unable to carry the volume of fluid needed, large pressure drops will result. Use guidelines in Table 4 to evaluate the suction and discharge lines. Remember, plugged screens and nozzles also can reduce spray output.

Table 4. Recommended hose sizes.

Pump output (gpm)	Suction	Discharge
	(inside diameter inches)	
< 12	¾	⅝
12–25	1	¾
25–50	1¼	1
50–100	1½	1¼

Strainers and Screens Check

The sprayer should be equipped with several strainers and screens. The more strainers and screens used, the less chance a nozzle will become plugged. A 10- to 20-mesh basket strainer should be used in the tank manhole. This strainer will stop large items such as label booklets. Sometimes these booklets are loosely attached to the container and can fall into the tank while adding chemicals.

A 50-mesh strainer should be placed on the outlet side of the pump and should be frequently cleaned. Using a large screen on the inlet side of the pump will keep sand, gravel, and debris from damaging the pump. Additional strainers should be placed after the flow control assembly. Cleaning a strainer is easier than cleaning each nozzle screen. Each nozzle should have a 50- to 100-mesh screen to stop any particles that may plug the nozzle. Check the manufacturer's recommendations for the exact screen size. Remember, partly plugged orifices and screens are hard to detect, so periodically clean them.

Spray Monitor and Controller Check

Spray monitors and controllers are becoming more popular to achieve uniform application, but they do not eliminate the good practices of sprayer inspection and calibration. System monitors record the operating conditions such as travel speed, pressure, and flow rate. Spray controllers are monitors with the added capability of automatic rate control. The controller goes a step further than a monitor and receives the actual application rate from the monitors and compares it to the desired rate. If a difference exists, the controller will adjust the application rate automatically (usually by adjusting pressure). Since these adjustments are a direct response to various sensors, it is important that these sensors are periodically calibrated. Do not assume the monitors are foolproof. Consult the manufacturer's operating manual to properly calibrate and adjust the sensors.

Conclusions

Spray equipment in good condition will apply chemicals properly if frequently calibrated and correctly operated. Manufacturers' manuals include tables to show rates of application for various nozzles, pressures, and ground speeds. Use this information to initially set up the sprayer, then use the methods described in this publication to evaluate and adjust the sprayer for accurate application.

Weight and Measures Conversions

Weight

16 ounces = 1 pound = 453.6 grams

1 gallon water = 8.34 pounds = 3.78 liters

Liquid Measure

1 fluid ounce = 2 tablespoons = 29.57 milliliters

16 fluid ounces = 1 pint = 2 cups

8 pints = 4 quarts = 1 gallon

Length

3 feet = 1 yard = 91.44 centimeters

16.5 feet = 1 rod

5280 feet = 1 mile = 1.61 kilometers

320 rods = 1 mile

Area

9 square feet = 1 square yard

43,560 square feet = 1 acre = 160 square rods

1 acre = .405 hectare

640 acres = 1 square mile

Speed

88 feet per minute = 1 mph

1 mph = 1.61 km/h

Volume

27 cubic feet = 1 cubic yard

1 cubic foot = 1,728 cubic inches = 7.48 gallons

1 gallon = 231 cubic inches

1 cubic foot = 0.028 cubic meters

Common Abbreviations and Terms Used:

gpm = gallons per minute

gpa = gallons per acre

psi = pounds per square inch

mph = miles per hour

rpm = revolutions per minute

gph = gallons per hour

fpm = feet per minute

Notes

Adapted with permission from *Fine Tuning a Sprayer with "Ounce" Calibration Method, http://pubs.ext.vt.edu/442/442-453/442-453.html*, Bobby Grisso, Virginia Cooperative Extension, 2009.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service
MF3174 December 2014