Calibrating a Low Pressure Ground Sprayer

Ronald T. Noyes
Extension Agricultural Engineer

H. Willard Downs
Extension Agricultural Engineer

John B. Solie
Research Agricultural Engineer

Richard W. Whitney
Research Agricultural Engineer

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Calibration is the process of adjusting or modifying spray equipment so it is capable of applying the desired rate of pesticide accurately and uniformly to the target crop of land area (Figure 1). The performance of any pesticide depends on the proper application of the correct amount on the target area. Most performance complaints about agricultural chemicals can usually be traced to errors in mixing or applying the chemical.

A Nebraska field study found that about one applicator in four was actually applying pesticides within label tolerances at the intended rate. Over 40 percent were under applying by an average of 35 percent, while 35 percent were over-applying by an average of nearly a third more chemical than they intended. Over 75 percent of the errors detected were the result of improper calibration. The study concluded that the annual cost to Nebraska corn producers as a result of over applications alone was over $9 million. The cost of under application was not calculated, but the study noted that reduced returns, because of lower production caused by poor control, were probably significant. The results of this study clearly show that accurate calibration of spray equipment is important and can pay big dividends to producers.

Variables Affecting Application Rate

Three variables affect the amount of pesticide mixture applied per acre:

1) nozzle flow rate.
2) ground speed of the sprayer, and
3) effective sprayed width per nozzle.

To calibrate a sprayer accurately the effect of each of these variables on sprayer output must be understood.

Nozzle Flow Rate - The flow rate through the nozzle varies with orifice tip size and nozzle pressure. Installing nozzles with a larger or smaller orifice size is the most effective way to change the sprayer's output.

Changes in nozzle pressure can also be used to increase or decrease sprayer output, but not as significantly as changes in orifice size. Pressure must be increased four times to double nozzle flow rate. For example, in order to increase the flow rate of a nozzle from .25 gallons per minute (gpm) at 20 pounds per square inch (psi) to .50 gpm, pressure would have to be increased to 80 psi (4 x 20). It should never be used to make major changes. Most nozzles work best at pressures between 15 to 30 psi. Pressures below 15 psi may distort the spray pattern, while pressures above 40 psi will increase spray drift.

Ground Speed - The spray application rate varies inversely with the ground speed. Doubling the ground speed of a sprayer reduces the gallons of spray applied per acre (gpa) by one half. For example. a sprayer applying 20 gpa at 3 mph would apply only 10 gpa at a speed of mph if all other tractors remained the same. A sprayer calibrated at 4 mph

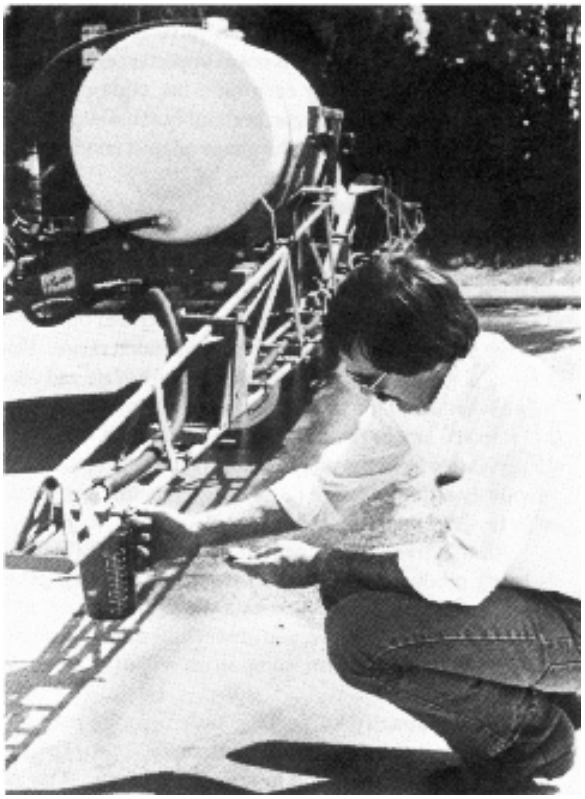


Figure 1. Calibration is the process of adjusting spray equipment to uniformly apply the desired rate of chemical.

but actually operated at 3 mph will over spray by 33 percent, significantly increased chemical costs and the potential for crop damage.

Sprayed Width Per Nozzle - The effective width sprayed per nozzle also affects the spray application rate. Doubling the effective sprayed width per nozzle will decrease the gallons per acre (gpa) applied by one-half. For example, if the nozzle is applying 40 gpa on a 20-inch spacing, a change to a 40 -inch spacing will decrease the application rate to 20 gpa.

Precalibration Checks

Before actually calibrating a sprayer, service the entire unit. Check that all nozzles are the same size and not worn. Check for uniform nozzle output and pattern and determine exactly how much liquid the sprayer tank holds. Install a pressure gauge on the boom to determine actual pressure at the nozzles.

Servicing - Clean all lines and strainers, making sure the strainers are in good condition and are the correct size and type for the chemical formulation that is to be applied, inspect all hoses for signs of aging, damage, and corroded fittings. or leaks. Check the pressure gauge to determine if it is working properly. Is the pressure holding constant? Does it read zero when the pump or boom valve is shut off? The actual accuracy of the gauge is not as important as is its ability to give the same reading each time the same pressure is produced. At least once a year, preferably at the beginning of the spraying season, check the gauge against another gauge which is known to be accurate.

Nozzle Output and Pattern - Check for uniformity of nozzle output and that the spray angles, spacing, and height are consistent. To check for uniform nozzle output, install the selected nozzle tips and check to be sure the tank is clean. Then partially fill the tank with clean water and operate the sprayer at a pressure within the recommended range. Place a container, such as a quart jar, under each nozzle and check to see whether all the jars fill in about the same time (Figure 2). Replace any nozzle tips that have an output that significantly varies times the output of the rest of the tips, have an obviously different fan angle, or have a non-uniform appearance in spray pattern.

An effective way to determine whether a uniform pattern is being produced and whether the boom is at the proper height is to spray some water on a warm dry surface, like a paved road or gravel drive, and observe the drying pattern. If the pattern is not uniform, some strips will dry slower than others.

Tank Capacity - Checking tank capacity may seem unnecessary, but unless the exact capacity of the sprayer's tank is known, it may lead to serious problems. This precalibration check; should be made at least once, and the data should be recorded. When determining application rates, the use of an inaccurate tank capacity is a common cause of many cases of under- and over-application. A tank thought to hold 200 gallons, but which actually holds 250 gallons, results in a built-in calibration error of 25 percent. The best and easiest way to accurately determine tank capacity is to fill the tank using any convenient container for which an exact capacity is known.

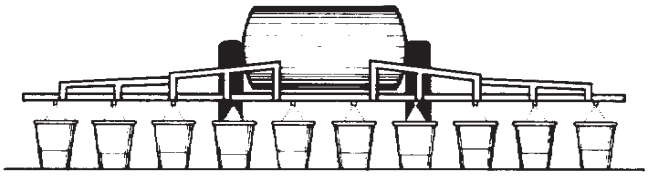


Figure 2. Place a container under each nozzle to see if all jars fill in about the same.

Another effective way of measuring tank capacity is with an accurate flow meter. A third way is to weigh the sprayer both empty and full. The difference between the two weights is the weight of the water in the tank. The capacity of the tank in gallons can then be determined by dividing this weight by 8.33 pounds which is the weight of one gallon of water.

Measuring Ground Speed

To apply pesticides accurately, a constant ground speed must be maintained. Field conditions such as surface roughness, softness, and slopes will all affect ground speed due to wheel slip and significantly change application rates. Tractor speedometers and tachometers are generally not a good means of determining ground speed because wheel slippage can result in speedometer reading errors of 25 percent or more. Changes in tire size can also affect speedometer readings. The most accurate way to maintain a constant ground speed is with a special sprayer speedometer that runs by a non-driven wheel. These speedometers are available from a number of spray-equipment manufacturers at reasonable prices and are a good investment if a considerable amount of spraying is done. Many of the sprayer monitors which are currently on the market also have the ability to accurately measure ground speed.

If an accurate speedometer is not available, the next best method to assure a constant ground speed is to measure the speed of the sprayer at a variety of throttle and gear settings. Do this in the field to be sprayed or a field that has conditions similar to those in the field to be sprayed. To measure ground speed, stake out a known distance in the field. Suggested distances are 100 feet for speeds up to 5 mph, 200 feet for speeds from 5 to 10 mph, and at least 300 feet for speeds above 10 mph. At the engine throttle setting and gear to be used during spraying, determine the travel time between the measured stakes in each direction. To ensure the greatest accuracy, the sprayer should be at least half full of liquid. Average the two speeds and use the following equation or chart in Table 1 to determine the ground speed.

$$\text{Speed (mph)} = \frac{D \times 60}{T \times 88}$$

D = the distance between the two stakes.

T = average time in seconds it takes to drive between the stakes.

The numbers 66 and 88 are used because 1 mph = 88 feet in 60 seconds.

Table 1. Time to Travel Distance (Seconds).

Ground Speed (mph)	3	4	5	6	7	8	9	10	12	15	20
Distance (ft.)											
100	23	17	14	11-	-	-	-	-	-	-	-
200	45	34	27	23	19	17	15	14	-	-	-
300	68	51	41	34	29	26	23	20	17	14	10

Calibration

The actual calibration of a field sprayer involves two important steps:

Step 1. Determine how much pesticide should be added to the sprayer's tank to achieve the desired application rate.

Step 2. Determine whether the sprayer is applying the correct number of gallons per acre of pesticide mixture.

Determining Sprayer Output With Nozzle Output Method

One of the easiest and most effective methods to determine whether the sprayer's output is actually what is desired is the nozzle output method. An advantage of this method is that it is done with the sprayer stationary and does not require that the sprayer he driven in the field. One limitation is that ground driven sprayers can not be calibrated by this method. In order to use this method, three pieces of information must be known:

1. Operating Pressure – will generally be in the 15 to 40 psi range depending on the type of nozzle used.
2. Ground Speed – speed normally ranges from 3 to 8 mph for pull-type farm sprayers, 5 to 12 mph tor self-propelled farm sprayers, and 10 to 20 mph tor commercial truck-mounted or floater-type sprayers.
3. Sprayed Width per Nozzle – varies with the type of nozzle arrangement used.

Calibrate a sprayer using the following method

Step 1. Fill the spray tank partially with water and operate the sprayer at the selected pressure. Use a container marked in ounces to collect the output of a nozzle for one minute or some convenient fraction of a minute. Make sure all nozzles are spraying uniformly and determine the average number of ounces per minute (opm) of output for each nozzle.

Step 2. Convert opm determined in Step 1 to gpm by dividing opm by 128 (the number of ounces in 1 gallon).

Step 3. Select the ground speed (mph) at which the sprayer is to be operated. This speed will normally be in the 3 to 8 mph range for tractor-mounted or pull-type sprayers, 5 to 12 mph for self-propelled farm sprayers, and 10 to 20 mph for truck-mounted floatation sprayers depending upon field conditions.

Step 4. Determine the sprayed width per nozzle (W) in inches. For broadcast spraying, "W" will equal the distance between nozzles. For band spraying, "W" will equal the band width. For row-crop spraying with two or more nozzles per row or band, "W" will equal row spacing or band width divided by the number of nozzles per row or band.

Step 5. Once these values are known, the sprayer's output in gallons per acre can be calculated using the following equations:

1. $GPM = \frac{OPM}{128}$

2. $GPA = \frac{GPM \times 5940}{MPH \times W}$

3. $GPA = \frac{OPM \times 5940}{128 \times MPH \times W}$

GPA = the sprayer's output in gallons per acre.

GPM = the nozzle output determined in Step 2 in gallons per minute.

5940 = a constant used to convert inches, gallons per minute, and miles per hour to gallons per acre. Using 6,000 makes the computation easier and results in an error less than one percent.

MPH = the ground speed selected in Step 3 in miles per hour.

W = the sprayed width per nozzle which was determined in Step 4 in inches.

128 = the number of fluid ounces per gallon.

For example, a pull-type field sprayer is set up to broadcast spray a herbicide with regular flat fan nozzles spaced 20 inches on center. A ground speed of S mph has been selected. The average collected nozzle output is 54 opm.

What is the application rate in gallons per acre? Using Equation (3).

$$GPA = \frac{54 \times 5940}{128 \times 5 \times 20} = 25.06 \text{ GPA}$$

Under this set of conditions, the sprayer will apply 25 gallons per acre. If this is not the application rate desired, then one or more conditions will need to be changed. A small-nozzle volume change can generally be accomplished by either raising or lowering the pressure within the pressure limitations of

the nozzle. A larger volume change can be accomplished by either changing the ground speed or by switching to larger or smaller nozzle tips. If 20 gpa was the desired application rate, a change in ground speed of

25 GPA/20 GPA x 5.0 MPH = 6.25 MPH

would provide the desired 20 gpa without nozzle or pressure changes. From Table 1, this would require that a ground distance of 200 feet be covered in 22 seconds.

Calibration Computers, Jars, and Nomographs

In recent years a number of calibration aids have been developed which further simplifies or even eliminates the use of mathematical equations in the calibration process. These techniques require the same pieces of information to be known or measured, such as pressure, ground speed, nozzle output, and effective spray width per nozzle. They eliminate the calculations involved through the use of a nomograph or graduated charts on the calibration jars. Calibration jars are available from a number of sources at prices of less than $15 and are effective when used according to the instructions which accompany them. A calibration flow meter is also available which gives a direct flow rate for each nozzle. Recently a computerized calibration kit has been developed by Spraying Systems that is available in English or metric units at a list cost of less than $80.

Computer Sprayer Calibration Kit

1. Spraying Systems Corporation (English or metric)
   North Avenue, Wheaton, IL 60188

Calibration Jar Sources

1. Broyhill Company
   N. Market Square, Dakota City, NE 68731
   (Spra-Check calibration bottle)

2. R & D Sprayers (Calibration Tumbler)
   790 E. Natchez, Opelousa, LA 70570

3. Farm Best Calibration Kit
   Farm Best, Inc.
   4446 Madison Ave, Kansas City, MO 64111

Calibration Flow Meter Sources

1. Sprayer Calibration Corporation
   P.O. Box M, Fort Collins, CO 80522
   (The McKenzie Calibrator)

Nomograph Method

The nomograph can be used to determine the values needed to calibrate a sprayer. It eliminates the need for mathematical calculations but requires that nozzle output be checked accurately with a container or flow meter that is graduated in ounces.

Two straight lines are required to use the nomograph. One line connects the left-hand scale for the broadcast rate and the right-hand scale for speed in miles per hour. The other line connects the effective width per nozzle on the top scale and the rate of flow per nozzle on the bottom scale. In using the nomograph, one unknown can be solved as long as the other three values are known. There is one important rule to follow: No matter which line is drawn first, the other line must pass through the point where the first line intersects the turning line.

Example: (See nomograph, Figure 3) A broadcast rate of 20 gallons per acre and a speed of 4 miles per hour is desired. The nozzles are spaced 20 inches apart on the boom. What should be the flow rate for each nozzle?

Answer: Draw a straight line from 20 gallons per acre (A) on the left-hand scale to 4 miles per hour (B) on the right-hand scale. Draw a second straight line from 20 inches (D) on the top scale through point C (point of intersection of first line and turning line) until the bottom scale is intersected at point E. The top scale of the bottom line gives the flow rate of the nozzle in gallons per minute tor use in selecting the proper nozzle from nozzle catalogs. In this example, a nozzle that discharges 0.27 gallons per minute or 34 opm at the desired pressure is needed. Use a calibrated measure as shown in Figure 2 and adjust the pressure regulator until this flow rate is obtained from each nozzle.

Worn nozzles may vary by plus or minus 5 to 10 percent from the desired flow rate. If more than 10 percent total variation is observed (target of 0.27 gpm or 34 opm with range from 0.256 to .283 gpm or 32.3 to 35.7 opm), replace worn nozzles with new nozzles and recheck calibration.

Determining the Amount of Chemical to put in the Tank

To determine the amount of pesticide to add to the spray tank, the recommended rate of pesticide, the capacity of the sprayer's tank, and the calibrated output of the sprayer must be known. A key concern here is to know the exact volume of the tank or the exact total volume of spray mixture required in cases where partial loads are required.

The recommended application rate of the pesticide is given on the label. The rate is usually indicated as pounds per acre tor wettable powders, and pints, quarts, or gallons per acre tor liquids. Sometimes the recommendation is given as pounds of active ingredient (pounds or ounces A.I.) per acre rather than the amount of total product per acre. The active ingredient must be converted to actual product in pounds or ounces per acre.

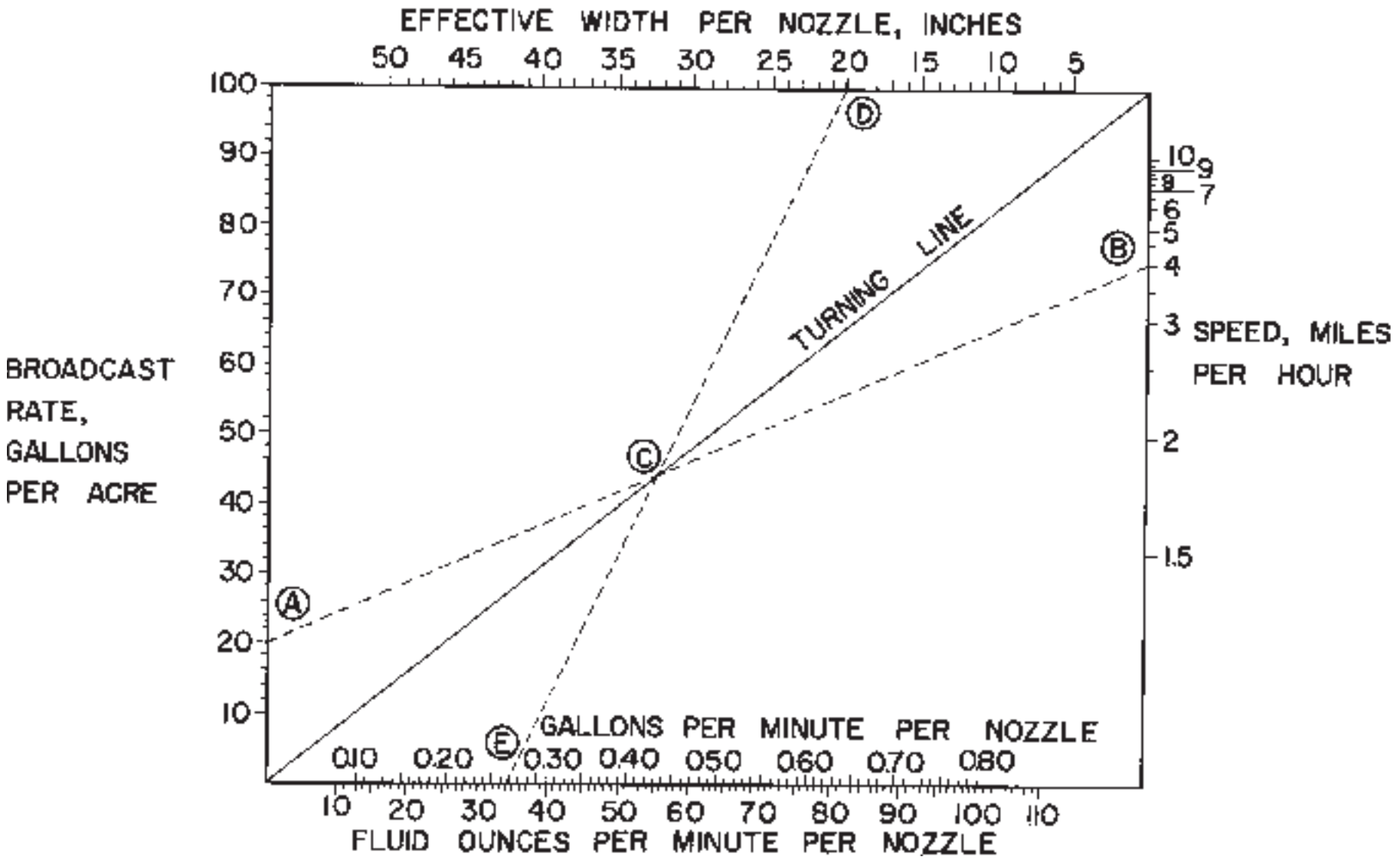
Dry Formulation

Example: An atrazine recommendation calls for 2 pounds of active ingredient per acre. Atrex (80-percent wettable powder) has been purchased. The sprayer has a 400-gallon tank and is calibrated to apply 20 gallons per acre. How much Atrex should be added to the spray tank?

Step 1. Determine the number of acres that can be sprayed with each tankful. The sprayer has a 400-gallon tank and is calibrated to apply 20 gallons per acre so 20 acres per tank can be covered.

Step 2. Determine the pounds of pesticide product needed per acre. Because not all of the product in the bag is active ingredient, more than 2 pounds of the product must

NOMOGRAPH FOR SPRAYER CALIBRATION



be added for each “acre’s worth” of water in the tank. To determine how much more, divide the amount of active ingredient needed per acre (2 pounds) by the percent of active ingredients in the product (80 percent which equals 0.80). Two and one-half (2.5) pounds of product will be needed for each “acre’s worth” of water in the tank to apply 2 pounds of active ingredient per acre.

Step 3. Determine the amount of pesticide to add to each tankful. Each tankful will spray 20 acres (Step 1), and 2.5 pounds of product per acre are required (Step 2). Therefore, 50 pounds (20 acres/tank X 2.5 lbs/acre = 50 lbs) of product will need to be added to each tankful to obtain the application rate.

Liquid Formulation

Example: A trifluraline recommendation calls for l pound of active ingredient per acre. Treflan4E which is a 4 pound active ingredient-per-gallon formulation has been purchased. The sprayer has a 300-gallon tank and is calibrated at 15 gallons per acre. How much Treflan should be added to the spray tank?

Step 1. Determine the number of acres that can be sprayed with each tankful. The sprayer has a 300-gallon tank and is calibrated for 15 gallons per acre, so 20 acres can be covered per tank.

Step 2. Determine the amount of product needed per acre by dividing the recommended A.I. per acre by the concentration of the formulation. To apply 1 pound of active ingredient per acre, one-fourth gallon or 1 quart of product is needed for each “acre’s worth” of water in the tank.

Step 3. Determine the amount of pesticide to add to each tankful. With each tankful, 20 acres will be sprayed (Step 1), and one-fourth gallon (1 quart) of product per acre is required (Step 2). Add 20 quarts (20 acres/tank x 1 quart per acre = 20 quarts) or 5 gallons of Treflan4E to each tankful.

Additional Information

For additional information on chemical application equipment and on weed, disease, and insect control, visit or call the Oklahoma Cooperative Extension Office in your county.

Companion Fact Sheets

BAE-1203 Reducing Drift from Ground Sprayers
BAE-1215 Selecting Nozzles for Low-Pressure Ground Sprayers
BAE-1217 The Low-Pressure Ground Sprayer
BAE-1218 Pumps for Low-Pressure Ground Sprayers

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- Extension has the built-in flexibility to adjust its programs and subject matter to meet new needs. Activities shift from year to year as citizen groups and Extension workers close to the problems advise changes.

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