CALIBRATION OF SPRAYING EQUIPMENT

H. Erdal Ozkan
Professor
Food, Agricultural and Biological Engineering Dept.
The Ohio State University
Columbus, OH 43210, USA

Calibration refers to **all** the operations that ensure the correct amount of pesticide will be applied to the treated area. These operations include: 1) calculating the amount of product, 2) mixing properly and safely, 3) adjusting equipment to deliver the desired rate uniformly across the spray swath, 4) determining effective swath/overlap, 5) checking accuracy during operation, and 6) detecting and correcting errors.

Application equipment must be calibrated periodically to achieve effective pest control and to reduce the potential for excessive pesticide residues remaining on sprayed surfaces. While applying too little pesticide may result in ineffective pest control, too much pesticide wastes money, may damage the crop and increases the potential risk of contaminating ground water and environment.

A survey of 53 private and municipal golf course pesticide applicators in Nebraska revealed that only one of six applicators applied pesticide carrier volumes within the acceptable error margin of $\pm$ 5 percent. Application errors ranged from 83 percent under application to 177 percent overapplication. Thirty-six percent of the applicators over applied pesticides by more than 5 percent of their intended application rate. The applicators overapplied pesticides by an average of 19 percent. The cost of overapplication for group using Daconil 2787 ranged from 12 cents per hectare to $16 per hectare. Faulty pressure gauges and improperly sized hoses and plumbing components were contributing factors to inaccurate tank-mix application rates and non-uniform applications. Varner et al. (1990).

A survey of 152 private and commercial applicators in Nebraska revealed that only one out of four farmers were applying pesticides within 5% of their intended application rate (Rider and Dickey, 1982). A follow-up field survey of 103 private pesticide applicators in Nebraska indicated that only 30% of the cooperators were applying herbicides within 5% of their intended application rate (Grisso et al., 1989). Twenty-six percent of the cooperators overapplied herbicides during a single application, with an average cost due to misapplication of $3.11/ha.

A survey conducted in South Carolina indicated that nearly 85% of applicators applied pesticides with errors greater than 10% when compared to intended rates (Wolak, 1989). Hofman and Hauck (1983) reported that only 11 of the 60 sprayers they calibrated in North Dakota were applying chemicals as the operator predicted. Calibration clinics conducted in Iowa and Ohio revealed that only 20 percent of sprayers calibrated were capable of applying a tank-mix within $\pm$ 5% of the intended application rate (Ozkan, 1987). Similar findings were reported from calibration clinics conducted in Montana and Colorado. This limited data indicates that in general, pesticide application accuracy continues to be a problem regardless of the geographic location. This problem, however, can be reduced to minimum with proper and frequent calibration of sprayers.

Sprayers should be calibrated several times a year. Changes in operating conditions and the type of chemical used require a new calibration. Frequent calibration is even more important with liquid application because nozzles wear out with use, increasing the flow rate. For example, tests conducted by Reichard et al. (1991) indicated that the flow rate of 0.8 liter-per-minute capacity brass nozzle increased by 10 percent after only three hours of use with a wettable powder material.

The results of the survey conducted by Varner et al.(1990) indicated a positive correlation between application accuracy and the frequency of calibration. Approximately 67 percent of the operators who calibrated before every spray operation had application errors below 5 percent while only 5 percent of those operators who calibrated their equipment less than once a year (once every two, three, four years) achieved the same degree of application accuracy.

A. Calibrating Liquid Application Equipment: Although there are many methods used to calibrate liquid application equipment, the methods described here are the most common. Choose a method that you are most comfortable with.

For safety, use water instead of actual chemical mixtures when calibrating. However, some carriers, such as liquid fertilizers, are much denser than water and may cause the nozzle flow rate to vary from the rate obtained with water. In this case, determine the average nozzle output with water and use a conversion factor that is usually listed in the nozzle manufacturer's catalog.

To calibrate a sprayer, you need a measuring tape, a stop watch or an ordinary watch with a second hand, and a measuring jar graduated in milliliters. A pocket calculator also will be handy. Regardless of the type of liquid application equipment you are calibrating, the calibration procedure requires checking the nozzle flow rate and the actual travel speed of the sprayer. Although the procedure is similar, steps involved in calibrating boom-type, manual backpack and hand gun sprayer are presented separately below.

Follow these steps when **calibrating low-pressure boom sprayers**.

Step 1. Fill the sprayer tank with water.

Step 2. Run the sprayer, inspect it for leaks and make sure all vital parts function properly.

Step 3. Determine the spray width per nozzle **(W)** in meters.

For broadcast application, W= Nozzle spacing

For band spraying, W= Band width

For directed spraying, $W = \frac{\text{Row spacing (or band width)}}{\text{Number of nozzles per row (or band)}}$

Step 4. Determine Travel Speed **(km/h)**.

To determine the travel speed, measure a known distance Use fence posts or flags to identify this distance. A distance over 50 m and a tank at least half full are recommended. Travel the

distance determined at your normal spraying speed and record the lapsed time in seconds. Repeat this step and take the average of the two measurements. Use the following equation to determine the travel speed in km/h:

$$\text{Travel Speed (km/h)} = \frac{\text{Distance (m)} \times 1000}{\text{Time(seconds)} \times 60}$$

Step 5. Determine Nozzle Flow Rate (L/min)

With the sprayer parked, run the sprayer at the same pressure level and catch the output from each nozzle in a measuring jar for one minute (or collect output for half a minute and then double the amount collected) to determine the nozzle flow rate in liters per minute. Check for clogs and clean the tip or replace any nozzle tips having flow rates 10 percent more or less than the average of the other nozzles checked, and/or having obviously different fan angles or patterns. Repeat the above process until the variation in discharge rate for all nozzles is within 10 percent of the average.

Step 6. Determine the Actual Application Rate (L/ha) using the following equation:

$$\text{L/ha} = \frac{\text{L/min} \times 600}{\text{(km/h)} \times \text{W}}$$

L/min: average nozzle flow rate in liters per minute
km/h: travel speed in kilometers per hour
W: effective spray width per nozzle in meters (as determined above)
600: constant to convert units to liters/hectare

Step 7. Compare the Actual Application Rate with the Recommended or Intended Rate

If the actual rate is more than 5 percent higher or lower than the recommended or intended rate, you must make adjustments in either the pressure or the travel speed or in both. If these changes don't bring the application rate to the desired range, then you may have to select a new set of nozzles with smaller or larger openings. (Refer to "Useful Formulas" to determine the new travel speed and/or the pressure rate.

Step 8. Recalibrate the Sprayer

Repeat steps 5 through 7 above until the application error is within 5 percent of the intended application rate.

The principles for **calibrating manual hand can and backpack sprayers** are essentially the same as those for boom sprayers outlined previously. Here are the steps involved in the calibration process:

Step 1. Measure and mark off an area equal to 100 square meter (such as 10 m x 10 m).

Step 2. Add a measured amount of water to the tank, spray the area and then measure the amount of water remaining in the tank. The difference between the amount in the tank before and after spraying is the amount used per 100 square meter.

Step 3. Compare the measured rate with the intended or recommended rate. If the difference is greater than ±5% of the intended rate, make necessary adjustments and recalibrate the sprayer.

An alternative method is to record the time required to spray 100 square meter and later catch and measure the spray from the nozzle (or nozzles) used for the same time period.

Calibrating a hand gun nozzle is similar to calibrating a backpack sprayer. Spray a known area and record the time required to cover this area. Then use a bucket to catch the spray from the hand gun for the time period elapsed during spraying of the marked area. Determine the application rate by measuring the amount of liquid in the bucket.

B. Calibration of Granular Herbicide Application Equipment: Herbicide labels list the rate at which the product should be applied. Some labels will also list the correct setting for some name-brand spreaders. However, these settings are just recommendations to provide a good reference point when calibrating spreaders. Seldom does a setting give the same application rate in all operating conditions and application sites. Variables such as particle size, particle density, particle shape, relative humidity, drop point of granules on the impeller plate, impeller speed and ground speed all affect the application rate and the distribution pattern. Therefore, granular applicators should be calibrated for each type of granular product being applied and for change in operator, weather and field conditions.

Before beginning to calibrate a granular applicator, be sure that it is clean and all parts are working properly. Always wear rubber gloves and other protective clothing to prevent contact with chemicals during cleaning and calibration of equipment and actual application of chemicals.

The primary purpose of calibration is to determine the actual delivery rate of a spreader regardless of its type. However, with rotary spreaders, it is also necessary to check and correct the distribution pattern.

"Delivery rate" refers to the average amount of product applied over a known area, and it usually is expressed in kg/ha or kg per 1,000 square feet. The easiest way for an operator to check the actual output rate is to collect and weigh the granules actually applied to a known area. You can do this by following one of the two methods explained below. Both methods are acceptable, but the first one produces a more precise calibration.

Method I

a) Spread out a plastic tarp of known size on the ground.

b) Operate the spreader at a known speed across the tarp.

c) Determine the area covered. If the swath width is wider than the tarp, the area covered is equal to the area of the tarp. If the swath is narrower than the tarp, multiply the swath width by the tarp length to determine the area covered. It is highly recommended you keep the tarp width wider than the swath width for a more accurate measurement of the delivery.

d) Place all the granules on the tarp into a container and weigh them.

e) Divide the weight of granules collected by the area covered to determine the actual delivery rate in grams per square meter.

f) Compare the measured (actual) delivery rate with the rate recommended on the label. Make proper adjustments and recalibrate the spreader until you reach the desired accuracy (a variation within $\pm$ 5 percent of the label recommendation is acceptable).

Method II

The second method is not as precise as the first one, but it is preferred by many operators because it does not require a tarp. However, the principle is the same. For calibrating, this area should be at least 50 m^2 for drop spreaders and 100 m^2 for rotary spreaders. Once you set up the known area that will be covered, follow the steps below to complete calibration.

1. Fill the spreader to a known level marked on the inside of the hopper.
2. Operate the spreader over the known area already set up.
3. Weigh the amount of material needed to refill the spreader to the mark. Record the weight in grams.
4. Grams of product actually applied per square meter can be calculated as follows:

$$\frac{\text{Amount needed to refill (grams)}}{\text{Area covered (sq. meter)}} = \text{Product applied } (g/m^2)$$

Drop-type spreaders provide fairly uniform **distribution of granules** across the swath width. The distribution is not affected much by product physical characteristics, weather conditions, etc. However, rotary spreaders are very sensitive to these variables, and patterns can be severely skewed if these variables are neglected. Therefore, always check the distribution pattern of granules when using rotary spreaders.

The best method to check the distribution pattern is to lay out a row of shallow cardboard boxes on a line perpendicular to the direction of travel (Figure 30). Boxes with partitions will prevent chemical particles from rebounding. All boxes should have the same area and height (0.20 m^2 area, 3 to 5 cm tall). Space the boxes 30 cm apart, and make sure the row is 1.5 to 2 times the width of the anticipated effective swath.

To conduct the test, fill the spreader at least half full, set it at the label setting for rate and pattern, and make three passes in the **same** direction over the boxes. Be sure to turn the spreader on and obtain proper travel speed before crossing the boxes.

Put the material for each box into a test tube, vial or small narrow bottle. When the bottles are placed side by side in order, a plot of the pattern is visible. The effective swath width is twice the distance out from the center of the spreader to the point where the rate is one-half the average rate at the center of the pattern. For example, if the first three to four bottles for the center have material 4 cm deep and the bottles from the 3-meter positions (3 m left of the spreader centerline or 3 m right of the centerline) have material 2 cm deep, the effective swath width is 6 m. Therefore, you should be making passes 6 m apart to provide a uniform coverage throughout the area covered.

In some cases, a rotary spreader's distribution pattern may not be uniform enough, even after all spreader adjustments have been made. A common recommendation in such cases has been to cut the rate of application in half to cover the field twice at right angles. However, research conducted by Parish (1986) revealed that cutting the rate in half and cutting the swath width in half while maintaining parallel swaths is more effective than the "right angle" method. The "half width" method is practical mainly for correcting severe pattern problems that remain after all mechanical adjustments to the spreader have been made.

There is always the question of which of the two modes of spreader operation -- continuous, back-and-forth mode or the circuitous, round-and-round mode -- gives a more uniform spreader distribution. Parish (1988) analyzed the distribution pattern data from 90 spreader test runs involving four spreaders with several products and pattern settings. They found that when the continuous spreader pattern is generally acceptable, there is statistically no advantage to using the more cumbersome circular mode of operation. However, if the basic spreader pattern remains badly skewed after all the spreader adjustments are made, the circular mode may help improve the overlapping pattern. However, the half-rate, half-width method with the continuous mode is probably more effective in such cases. It is also easier to use and requires little additional travel over the turf area.

Mixing and Loading Chemicals

Mixing the pesticide thoroughly and carefully is an important step in good sprayer operation. Incomplete mixing results in varied application rates--too high at times, too low otherwise. Some chemicals, when mixed improperly with others, form a thick, mayonnaise-like mixture that will not spray properly and is difficult to clean out of the sprayer. Always read the label for proper mixing sequence, and test the compatibility of chemicals in a small container before mixing.

Generally, when preparing the spray mixture, fill the tank half full of water and pour in the correct amount of chemical while the pump is running. Then finish filling the tank. When using wettable powders, again fill the tank half full, make a slurry in a separate container or through an inductor system, and then add the slurry to the tank to ensure good mixing. Rinse the slurry container three times, pouring the rinsate into the tank. Finally, finish filling the tank with water.

You can spend hours in the field calibrating your sprayer to achieve the desired accuracy, but your efforts are wasted if you don't know how much chemical to put in the tank. In a survey conducted by Rider and Dickey (1982), 38 percent of the applicators failed to add the correct amount (within $\pm$ 5% of the required amount)

of chemical to the tank. In South Carolina, 76% of the applicators surveyed had tank-mix errors greater than 10% (Wolak, 1989).

The amount of chemical needed per tankful depends on the recommended rate and the size of area you can treat per tank of spray. Calculations are the same whether you are using a manual backpack sprayer or a powered boom sprayer. Assuming that a boom sprayer is to be used, the steps involved in determining the right amount of pesticide to add to the tank are: 1) Determine the area (hectares) to be treated per tank. To determine this, divide the tank capacity by the L/ha application rate. 2) Next, find the amount of pesticide needed per tank by multiplying the number of hectares treated per tank with the amount of actual chemical to be applied per hectare.

Sometimes, chemical manufacturers give recommended rates in terms of active ingredient (A.I.) to be used per acre rather than the amount of total product per acre. In these cases, calculate the amount of material to be applied as shown in examples 2 and 3 for dry chemicals and liquid chemicals, respectively.

USEFUL FORMULAS

* **To determine travel speed**

$$\text{Travel speed (km/h)} = \frac{\text{Distance (m)} \times 1000}{\text{Time (sec)} \times 60}$$

* **To calculate the resulting application rate (L/ha) for any change in travel speed (km/h)**:

$$(\text{L/ha})_2 = \frac{(\text{L/ha})_1 \times (\text{km/h})_1}{(\text{km/h})_2}$$

* **To determine the desired travel speed (km/h) when changing application rate (L/ha):**

$$(\text{km/h})_2 = \frac{(\text{L/ha})_1 \times (\text{km/h})_1}{(\text{L/ha})_2}$$

* **To determine the resulting application rate (L/ha) when changing nozzle pressure:**

$$(\text{L/ha})_2 = (\text{L/ha})_1 \times \text{SQRT} \{ \text{kPa}_2 / \text{kPa}_1 \}$$

* **To determine the desired pressure (kPa) that will produce a desired application rate (L/ha):**

$$\text{kPa}_2 = \text{kPa}_1 \times \{ (\text{L/ha})_2 / (\text{L/ha})_1 \}^2$$

* **To determine the resulting nozzle flow rate (L/min) when changing nozzle pressure**

$$(L/min)_2 = (L/min)_1 \times SQRT \{ kPa_2 / kPa_1 \}$$

$(L/ha)_2$, $(L/ha)_1$: Desired and measured application rates, respectively
$(km/h)_2$, $(km/h)_1$:Desired and measured travel speeds, respectively
kPa_2, kPa_1 :Desired and measured spraying pressures, respectively
$(L/min)_2$, $(L/min)_1$: Desired and measured nozzle flow rates, respectively

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