No-till requires some adjustments in pesticide application equipment compared to intensive tillage systems. Because soil incorporation of herbicides can destroy crop residue, no-till systems typically use contact herbicides and/or residual herbicides that are carried into the soil by rainfall or irrigation. Applying herbicides in heavy residue does not require additional active ingredients, but may require higher spray volumes for coverage and penetration of crop residue. The use of herbicide resistant crops has reduced the need for many soil-incorporated herbicides and increased the amount of foliar or postemergence herbicides.

Proper equipment adjustment and product selection is critical for satisfactory performance. Inaccurate pesticide application is expensive. It can result in wasted pesticide, marginal pest control, and excessive carryover contributing to water contamination and/or crop damage. Better application equipment and new techniques that allow for smaller dosages of crop protection products and reduce drift and residue have become increasingly important in minimizing harmful effects of crop protection products on the environment.

**Low-Pressure Field Sprayers**

Sprayers are available in various types and sizes, each designed for a specific application. For applying crop protection products in agriculture, applicators use low-pressure sprayers more than any other kind of application equipment. Tractor-mounted, pull-type, and self-propelled low-pressure sprayers are available in many models and for a wide range in cost. Spray pressures typically range from 15 to 70 pounds per square inch (psi) and application rates can vary from less than 5 to 30 gallons per acre (GPA). All low-pressure sprayers have several basic components: a pump, tank, agitation system, flow-control assembly, and a distribution system.

**Sprayers for No-till Crop Production**

Optimal use of sprayers for No-till crop production requires:

- Understanding proper equipment types for specific applications
- Understanding variables affecting application rates
- Performing accurate calibrations to determine chemical application
- Calculating the gallons of spray to be applied per acre

At the end of the distribution system is the spray nozzle.

Keep spray equipment in good condition; calibrate frequently, and operate as recommended for specific field conditions. Manufacturers’ manuals include tables to show application rates in GPA for various nozzles, pressures, nozzle spacing, and ground speeds under ideal conditions. Use this information to adjust the sprayer; then calibrate and fine-tune the sprayer for accurate application.

**Nozzle Types**

Selecting the correct type and size of spray nozzle is essential for each application. The nozzle determines the amount of spray applied to an area, the uniformity of the application, the coverage of the sprayed surface, and the amount of drift. Although nozzles have been developed for practically every kind of spray application, only a few types - extended range flat-fans (Figure 1), Turbo flooding flat-fans, Turbo flat-fans, venturi flat-fans, and drift reduction pre-orifice flat-fans are commonly used in the application of crop protection products.
An emphasis in nozzle design during the past few years has resulted in a vast improvement in spray quality. You can minimize drift by selecting nozzles that give the largest droplet size while providing adequate coverage at the intended application rate and pressure.

Spray nozzle assemblies consist of a body, cap, check valve, and nozzle tip (Figure 2). Various types of bodies and caps (including color-coded versions) and multiple nozzle bodies are available with threads as well as quick-attaching adapters. Nozzle tips are interchangeable in the nozzle cap and are available in a wide variety of materials, including hardened stainless steel, stainless steel, brass, ceramic, and various types of plastic. Hardened stainless steel and ceramic are the most wear-resistant materials, but they are also the most expensive. Stainless steel tips have excellent wear resistance with either corrosive or abrasive materials. Plastic tips are resistant to corrosion and abrasion, and are proving to be very economical tips for applying crop protection products. Brass tips have been very common, but they wear rapidly when used to apply abrasive materials, such as wettable powders, and are corroded by some liquid fertilizers. Other types should be considered for more extensive use. See Table 1 for information about nozzle nomenclature.

### Variables Affecting Application Rate/Volume (GPA)

Three variables affect the amount of spray material applied per acre: (1) the nozzle flow rate, (2) the ground speed of the sprayer, and (3) the width sprayed per nozzle. To calibrate and operate a sprayer properly, you must understand how each of these variables affects sprayer output.

The nozzle flow rate varies with the size of the tip, the nozzle pressure, and the density of the spray liquid. Installing a nozzle tip with a larger orifice, increasing the pressure, and decreasing the density of the spray liquid all increase the flow rate. To increase the nozzle output, you must multiply the pressure by the square of the desired increase in flow rate. In other words, doubling the pressure will not double the nozzle flow rate. To double the flow rate, you must increase the pressure four times. For example, to double the flow rate of a nozzle from 0.2 gallons per minute at 10 psi to 0.4 gallons per minute, the pressure must be increased to 40 psi (4 x 10).

Pressure changes should not be used to make major adjustments in the application rate. To obtain a uniform spray pattern and minimize drift, you...
should maintain the operating pressure within the recommended range for each nozzle. The pressure can be changed, however, to correct for minor variations in flow rate resulting from nozzle wear.

The spray application rate varies inversely with the ground speed. Doubling the ground speed (MPH) of the sprayer reduces the application rate (GPA) by one-half. For example, a sprayer applying 20 GPA at 4 MPH would apply 10 GPA if the speed were increased to 8 MPH while the pressure remained constant.

Many low-pressure field sprayers have a metering control system that maintains a constant application rate while operating over a range of travel speeds. All metering systems now in use, such as ground-driven piston pumps, electronic feedback control systems, and various centrifugal pump arrangements, vary the nozzle pressure to compensate for changes in travel speed, keeping the application rate constant. Although all the systems work over a wide range of travel speeds, the spray nozzle limits the range of speeds at which precise application can be obtained. Because of the possibilities for dramatic pressure increases while using such systems, a serious potential for spray drift could occur through a fixed orifice nozzle.

To regulate the flow in proportion to travel speed, the rate of increase in nozzle pressure must vary with the square of the rate of increase in speed. For example, if the sprayer is traveling at 4 MPH at a nozzle pressure of 30 psi, increasing the speed to 8 MPH will require increasing the nozzle pressure to 120 psi to maintain the same flow volume. Remember, a fourfold change in pressure drastically reduces the droplet size, which may result in increased drift. The pattern width and distribution pattern may also be affected. For uniform application, the travel speed should be held as nearly constant as possible, even when using controlled metering systems.

To apply crop protection products accurately, you must maintain the proper ground speed. Do not rely on a conventional speedometer as an accurate indicator of speed. Slippage of the drive wheels can result in speedometer errors exceeding 20 percent. Electronic wheel speed sensors, radar guns, and GPS give more accurate readings since they do not depend on the drive wheels for speed measurements. Changes in tire size also affect speedometer readings, and the accuracy of all speedometers should be checked periodically.

The effective width sprayed per nozzle also affects the spray application rate. Doubling the effective width sprayed per nozzle decreases the gallons per acre (GPA) applied by one-half. For example, if applying 20 GPA with flat-fan nozzles on 20-inch spacings, changing to flooding nozzles with the same flow rate on 40-inch spacings will decrease the application rate from 20 GPA to 10 GPA.

**Calibration**

Accurate calibration is the only way to know how much chemical is applied. Even with the widespread use of electronics to monitor and control the application of crop protection products today, a thorough sprayer calibration procedure is essential to ensure against misapplication. Failure to calibrate a sprayer can injure the crop, cause potential pollution, and waste money. In addition to calibrating the sprayer at the start of the season, recalibrate regularly. Abrasive pesticide formulations can wear nozzle tips resulting in increased nozzle flow rate and the development of poor spray patterns.

To obtain uniform coverage, you must consider the spray angle, spacing, and height of the nozzle. The height must be readjusted for uniform coverage with various spray angles and nozzle spacings. Do not use nozzles with different spray angles on the same boom for broadcast spraying. Be sure the nozzle tips are clean. If necessary, clean with a soft bristle brush. A nail, wire, or pocket knife can damage the tip and ruin the uniformity of the spray pattern. While the sprayer is running, observe each spray tip for any distortions in the patterns.

Worn or partially plugged nozzles produce non-uniform patterns. Misalignment of nozzle tips is a common cause of uneven coverage. The boom must be level at all times to maintain uniform coverage. Skips and uneven coverage will result if one end of the boom is allowed to droop. A good method for determining the exact nozzle height to produce the most uniform coverage is to spray warm water on a warm surface, such as a road, and observe the drying rate. Streaks in the spray pattern should be obvious. Replace nozzles that not performing correctly.

Once the sprayer is operating properly, you are ready to calibrate. There are many methods for calibrating low-pressure sprayers, but they all involve the use of the variables discussed in the following section. Any technique for calibration that provides accurate and uniform application is acceptable. No single method is best for everyone.

The calibration method described below has four advantages. First, it allows you to select the number of gallons to apply per acre and to complete most of the calibration before going to the field. Second, it provides a simple means for frequently adjusting the calibration to compensate for changes due to nozzle wear. Third, it can be used for broadcast, band, directed, and row crop spraying. This method requires knowledge of nozzle types and sizes and the recommended operating pressure ranges for each type of nozzle used. Finally, when using the method below, the applicator will have a better understanding of how each variable will affect the application rate. As each of the variables change,
Select a nozzle that will give the flow rate required from each nozzle in gallons per minute (GPM) by using a nozzle catalog, tables, or the following equation. Using Equation 2 allows the applicator to determine flow rates for each application scenario needed for the application season. This can be done before the application season begins, thus not interfering with critical time available during the application time.

\[
(GPA \times MPH \times W)
\]

(Equation 2) \[\frac{GPA \times MPH \times W}{5,940} = GPM\]

The gallons of spray applied per acre can be determined by using the following equation:

\[
GPA = \frac{GPM \times 5,940}{MPH \times W}
\]

(Equation 1) GPA = gallons per acre or desired output
GPM = output per nozzle in gallons per minute
MPH = ground speed in miles per hour
W = effective width sprayed per nozzle in inches
5,940 = a constant to convert gallons per minute, miles per hour, and inches to gallons per acre

The size of the nozzle tip will depend on the application rate (GPA), ground speed (MPH), and effective width sprayed (W) planned. Some manufacturers advertise “gallon-per-acre” nozzles, but this rating is useful only for standard conditions (usually 30 psi, 4 MPH, and 20-inch spacing). The gallons-per-acre rating is useless if any one of the conditions varies from the standard.

Most applications will begin with reading the label to decide what carrier volume (GPA) is recommended with the chosen product. With a selected GPA, a more exact method for choosing the correct nozzle tip is to determine the gallons per minute (GPM) required for the conditions. Then select nozzles that provide this flow rate when operated within the recommended pressure range. By following the five steps described below, the nozzles required for each application can be selected well ahead of the spraying season.

**Step 1.** From the label information, select the spray application rate in gallons per acre (GPA). Pesticide labels recommend ranges for various types of equipment. The spray application rate is the gallons of carrier (water, fertilizer, etc.) and pesticide applied per treated acre.

**Step 2.** Select or measure an appropriate ground speed in miles per hour (MPH) according to existing field conditions. Do not rely on speedometers as an accurate measure of speed. Slippage and variation in tire sizes can result in speedometer errors of 20 percent or more. If you do not know the actual ground speed, you can easily measure it. (Instructions for measuring ground speed are given below.)

**Step 3.** Determine the effective width sprayed per nozzle (W) in inches.

For broadcasting spraying, \( W = \) the nozzle spacing
For band spraying, \( W = \) the band width
For row-crop applications, such as spraying from drop pipes or directed spraying,

\[
W = \frac{\text{row spacing (or band width)}}{\text{number of nozzles per row (or band)}}
\]

**Step 4.** Determine the flow rate required from each nozzle in gallons per minute (GPM) by using a nozzle catalog, tables, or the following equation. Using Equation 2 allows the applicator to determine flow rates for each application scenario needed for the application season. This can be done before the application season begins, thus not interfering with critical time available during the application time.

**Step 5.** Select a nozzle that will give the flow rate determined in Step 4 when the nozzle is operated within the recommended pressure range. You should obtain a catalog of available nozzle tips or view on-line. These catalogs and on-line information can be obtained free of charge from equipment dealers or nozzle manufacturers. If you decide to use nozzles you already have, return to Step 2 and select a speed that allows operation within the recommended pressure range.

**Herbicide Band Applications for Cost-Effective Weed Control**

Band applications of herbicides can reduce costs for postemergent and preemergent weed control treatments. In band applications, the treated acre is the acres actually sprayed, and depending on the row spacing and the band width, is some fraction of the total field acres. Remember, herbicides are applied in bands at the same rate of active ingredients per treated acre as in broadcast applications. Treating a field with 30-inch rows in 15-inch bands has the effect of reducing the herbicide cost by one-half.

When banding soil-applied herbicides to control weeds in row crops, use spray tips designed for band application. They are commonly referred to as ‘even flat spray’ tips and are designated in the nozzle nomenclature with the letter ‘E.’ Even flat spray tips are designed to apply a uniform pattern on the target across the width of the angle with no overlap required. Extended range flat spray tips on the other hand are designed to apply a tapered edge pattern, and thus would not uniformly cover the targeted band width requiring 50 to 60 percent overlap (25 to 30 percent on each edge). For even spray tips, the nozzle spray angle and height above the target will determine the spray width.

Band applications can also be used to apply postemergence materials. To obtain thorough cov-
Determine the required flow rate for

- Operate the sprayer in the field at the

Sprayers for No-till Crop Production

Now that you have selected and installed the proper nozzle tips (Steps 1 to 5) you are ready to complete the calibration of your sprayer (Steps 6 to 10 below). Check the calibration every few days during the season or when changing the crop protection products being applied. New nozzles do not lessen the need to calibrate because some nozzles `wear in,' increasing their flow rate more rapidly during the first few hours of use. New nozzles can also come from the factory with flow or pattern defects. The electronics component of the spray system does not necessarily alert you to these problems. Once you have learned the following method, you can check application rates quickly and easily.

**Step 6.** Determine the required flow rate for each nozzle in ounces per minute (OPM). To convert GPM (Step 4) to OPM, use the following equation:

\[
\text{OPM} = \text{GPM} \times 128 \quad (\text{1 gallon} = 128 \text{ ounces})
\]

(Equation 3)

**Step 7.** Collect the output from one of the nozzles in a container marked in ounces. Adjust the pressure until the ounces per minute (OPM) collected is the same as the amount determined in Step 6. Check several other or all of the nozzles to determine if their outputs fall within five to 10 percent of the desired OPM.

If it becomes impossible to obtain the desired output within the recommended range of operating pressures, select larger or smaller nozzle tips or a new ground speed, then recalibrate. It is important for spray nozzles to be operated within the recommended pressure range. The range of operating pressures is indicated at the nozzle tip. Line losses, nozzle check valves, etc., may require the main pressure gauge at the boom or at the controls to read much higher.

**Step 8.** Determine the amount of pesticide needed for each tank or for the acreage to be sprayed. Add the pesticide to a partially filled tank of carrier (water, fertilizer, etc.). Then add carrier to the desired level with continuous agitation.

**Step 9.** Operate the sprayer in the field at the ground speed measured in Step 2 and at the pressure you determined in Step 7. The application rate selected in Step 1 will be spraying. After spraying a known number of acres, check the liquid level in the tank to verify that the application rate is correct.

**Step 10.** Check the nozzle flow rate frequently. Adjust the pressure to compensate for small chang-
es in nozzle output due to nozzle wear or variations in other spraying components. Replace the nozzle tips and recalibrate when the output has changed five to 10 percent or more from that of a new nozzle, or when the pattern has become uneven.

To apply crop protection products accurately, proper ground speed must be maintained. Because speedometers do not always provide an accurate measure of speed, check the accuracy of the speedometer with an electronic kit or radar gun. If the sprayer does not have a speedometer, or if the speedometer is not accurate, measure the speed at all of the settings planned in the field. By measuring and recording the ground speed at several gear and throttle settings, remeasuring speed each time you change settings will be unnecessary.

To measure ground speed, lay out a known distance in the field you intend to spray or in another field with similar surface conditions. 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 in the gear you plan to use during spraying with a half-loaded sprayer, determine the travel time between the measured stakes in each direction. Average these speeds and use the following equation to determine ground speed.

\[
\text{Speed (MPH)} = \frac{\text{distance (feet)} \times 60}{\text{time (seconds)} \times 88}
\]

1 MPH = 88 feet per 60 seconds

Once speed is decided, record the throttle setting and drive gear used.

**Droplet Size Considerations**

Droplet size will influence coverage and drift. The nozzles typically used to apply herbicides produce droplets that vary greatly in size (Figure 3). Large droplets, which will help mitigate spray drift, may not provide good coverage. Very small droplets lack the momentum needed toward the target and are prone to drift under windy conditions. The range of droplets from a nozzle is also affected by liquid flow rate (size of nozzle orifice), liquid pressure, and physical changes to nozzle geometry and operation.

To help applicators select nozzles and use them at the most optimum droplet size range for a given situation, ASABE (American Society of Agricultural and Biological Engineers) has developed a classification system. According to this system, spray quality from a nozzle can be classified as: Very Fine; Fine, Medium, Coarse, Very Coarse, and Extremely Coarse (Table 1).
Currently, medium to coarse spray droplets (approximately 300-500 microns) are recommended by nozzle manufacturers for application of herbicides. In fact, company labels may specify the droplet size suggested based on the above classification system. Contact herbicides may need to be on the smaller end of the range to achieve better surface coverage, while translocated materials are expected to work effectively at the upper end of the range. Since most nozzle sizes will span a range of droplets sizes, dependent on the operating pressure, it is important to select the nozzle type and pressure option that closely matches the 300 to 500 micron size recommended. To achieve this, calibration to determine needed flow rate or orifice size must be done in conjunction with matching pressure, nozzle type, orifice size, and speed to the desired droplet size.

It will be necessary to add this step to the set-up of the sprayer to optimize the herbicide application for increased coverage and minimized drift.

Consulting the nozzle manufacturer’s droplet sizing charts is essential. Websites and manufacturer’s literature is available for additional help. Nozzle manufacturer’s charts can help you determine what pressure to use for the nozzle type selected to produce the mid-fine to mid-medium quality spray.

Though sprayers have become more complex than their predecessors, there are a lot of similarities. The keys to successful sprayer operation are to select appropriate nozzles and calibrating for desired operating conditions. Following the simple tips presented here will enable accurate and effective chemical application.

Figure 3. Different nozzles create droplet patterns used for a variety of purposes. (Refer to Table 1 for droplet size categories.)