



# SPRAYER NOZZLES: Selection and Calibration

Prepared by Monte P. Johnson, Entomology, and Larry D. Swetnam, Agricultural Engineering

The proper selection of a nozzle type and size is essential for proper pesticide application. This publication covers nozzle description, recommended uses, selection of the proper nozzle type, and the "ounce" calibration method. A listing of nozzle manufacturers also is included.

The proper selection of a nozzle type and size is essential for proper pesticide application. The nozzle is a major factor in determining the amount of spray applied to an area, the uniformity of application, the coverage obtained on the target surface, and the amount of potential drift.

Nozzles break the liquid into droplets, form the spray pattern, and propel the droplets in the proper direction. Nozzles determine the amount of spray volume at a given operating pressure, travel speed, and spacing. Drift can be minimized by selecting nozzles that produce the largest droplet size while providing adequate coverage at the intended application rate and pressure.

Minimizing drift is especially important for herbicides.

## Nozzle Description

Nozzle types commonly used in low-pressure agricultural sprayers include flat-fan, flood, raindrop, hollow-cone, full-cone, and others. Special features, or subtypes such as "extended range," are available for some nozzle types.

### Flat-fan

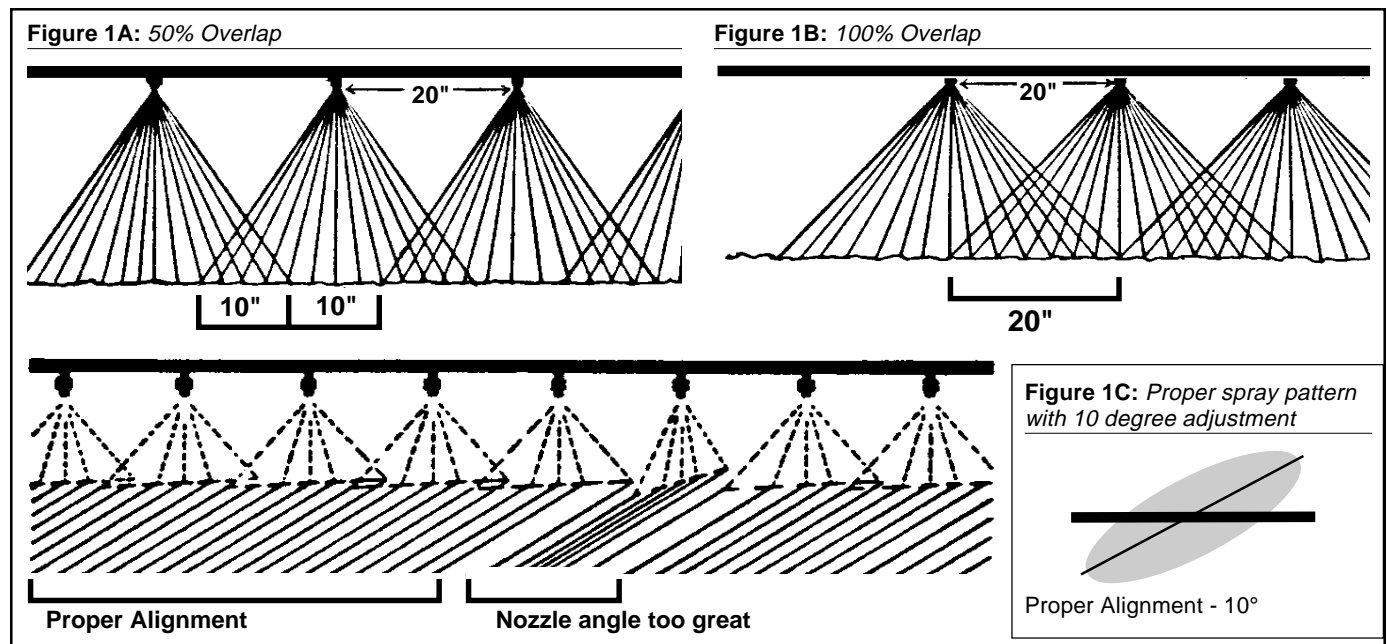
Flat-fan nozzles are widely used for broadcast spraying of herbicides. These nozzles produce a tapered-edge, flat-fan spray pattern (Figure 2A). These nozzles have several subtypes, such as standard flat-fan, even flat-fan, low pressure flat-fan, extended-range flat-fan, and some special types such as off-center flat-fans and twin-orifice flat-fans.

The **standard flat-fan** normally operates between 30 and 60 pounds per square inch (psi), with an ideal range between 30 and 40 psi.

The **even flat-fan** nozzles (Figure 2B) apply uniform coverage across the entire width of the spray pattern. They are used for banding pesticide over the row and should not be used for broadcast applications. The band width can be controlled with the nozzle height and the spray angle.

The **low pressure flat-fan** develops a normal flat-fan angle and spray pattern at operating pressures between 15 and 20 psi. Lower pressures result in larger droplets and less drift, but a low-pressure nozzle produces a smaller droplet at the same pressure as a standard nozzle.

The **extended range flat-fan** (Figure 2C) provides excellent drift control when operated between 15 and 25 psi. This nozzle is ideal for an applicator who likes the



uniform distribution of a flat-fan nozzle and wants lower operating pressures for drift control. Since extended range nozzles have an excellent spray distribution over a wide range of pressures (15-60 psi), they are ideal for sprayers equipped with flow controllers.

The special feature flat-fan nozzle, such as the **off-center flat-fan**, is used for boom end nozzles so a wide swath projection is obtained. The **twin-orifice flat-fan** (Figure 2D) produces two spray patterns — one angled 30 degrees forward, and the other directed 30 degrees backward. The droplets are small due to the atomizing by two smaller orifices. The two spray directions and smaller droplets improve coverage and penetration, a plus when applying postemergence contact herbicides. To produce fine droplets, the twin-orifice usually operates between 30 and 60 psi.

Flat-fan nozzles are available in several spray angles. The most common spray angles are 65, 73, 80, and 110 degrees. Recommended nozzle heights for flat-fan nozzles during broadcast application are given in Table I. Figures 1A and 1B illustrate two spray overlap percentages. Figure 1C illustrates proper spray pattern. The spray pattern will be uneven if nozzles are not aligned properly on the spray boom. Rotate nozzles about ten degrees from the axis of the boom to prevent droplets from adjacent nozzles from touching but still allow for proper overlap of the spray pattern.

The correct nozzle height is measured from the nozzle to the target, which may be the top of the ground, growing canopy, or stubble. Use 110-degree nozzles when booms are at lower heights and 80-degree nozzles when booms are higher.

Although wide-angle nozzles produce smaller droplets that are more prone to drift, the reduction of boom height reduces the drift potential more than droplet size. The nozzle spacing and orientation should provide for 100 percent overlap at target height. Nozzles should not be oriented more than 30 degrees from vertical.

The following are examples of nozzle numbering systems by two manufacturers. Spraying Systems Company\* identifies its flat-fan nozzles with a four or five digit number. The first numbers are the spray angle, and the other numbers signify the discharge rate at rated pressure. For example, an 8005 has an 80-degree spray angle and will apply 0.5 gallons per minute (GPM) at rated pressure of 40 psi. An 11002 nozzle has a 110-degree spray angle and will apply 0.2 GPM at rated pressure of 40 psi. Additional designations are “SS” (stainless steel), “HSS” (hardened stainless steel), and “VS” (color-coded stainless steel).

Delevan\* flat-fan nozzles are identified by “LF” or “LF-R,” which reflect the standard and extended range flat-fan nozzles. The first numbers are the spray angle followed by a dash and then the discharge rate at rated pressure. For example, an LF80-5R is an extended range nozzle with an 80-degree spray angle and will apply 0.5 GPM at the rated pressure of 40 psi.

### Flood

Flood nozzles (Figure 2E) are popular for applying suspension fertilizers where clogging is a potential problem. These nozzles produce large droplets at pressures of 10 to 25 psi. The nozzles should be spaced less than 60

**Table 1. Suggested minimum spray heights**

Spray Angle Degrees	----- Spray Height (inches) -----			
	20" spacing --- overlap ---		30" spacing --- overlap ---	
65	30%	100%	30%	100%
73	22-24	NR	NR	NR
80	20-22	NR	29-31	NR
80	17-19	26-28	26-28	NR
110	10-12	15-17	14-18	25-27

NR-Not recommended if height is above 30 inches.

inches apart. The nozzle orientation should be set for 100 percent overlap. These nozzles are generally not suited for contact herbicide applications.

Nozzle spacing between 30 and 40 inches produces the best spray patterns. Pressure influences spray patterns of flooding nozzles more than flat-fan nozzles. However, the spray pattern is not as uniform as with the flat-fan nozzles, and special attention to nozzle orientation and correct overlap is critical. Other than fertilizer suspensions, these nozzles are most often used with soil-incorporated herbicides with spray kits mounted on tillage implements.

Flooding nozzles are designated “TK” by Spraying Systems and “D” by Delevan. The value following the letters is the flow rate times 10 at rated pressure of 10 psi. For example, TK-SS2 or D-2 are flood nozzles that apply 0.2 GPM at 10 psi.

### Raindrop

Raindrop nozzles produce large drops in a hollow-cone pattern at pressures from 20 to 50 psi. The “RA” Raindrop nozzles are used for herbicide incorporation and are usually mounted on tillage implements. When used for broadcast application, nozzles should be oriented 30 degrees from the horizontal. The spray patterns should be overlapped 100 percent to obtain uniform distribution. These nozzles are not satisfactory for postemergence or non-incorporated herbicides because the droplet size is too large.

### Hollow-cone

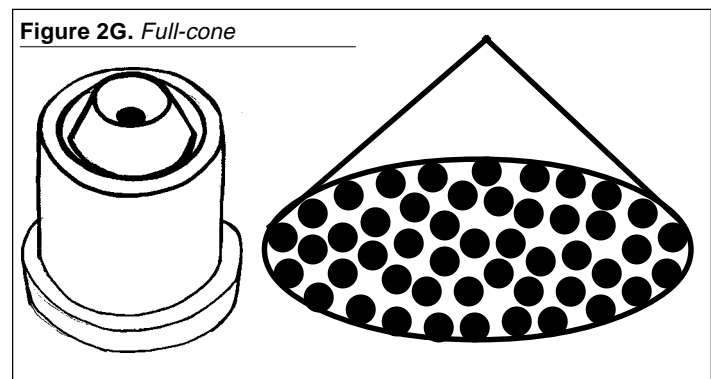
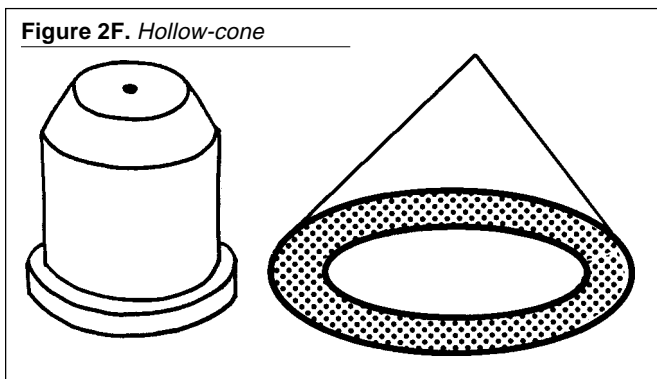
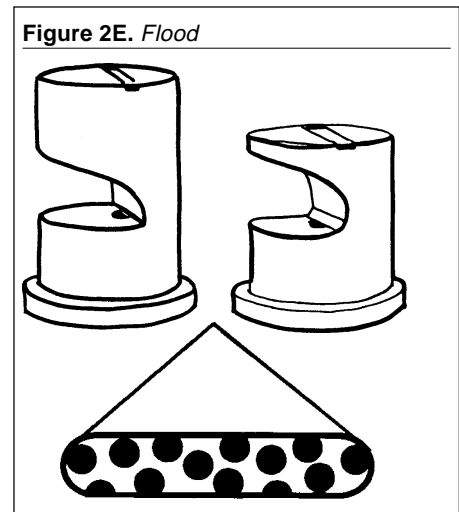
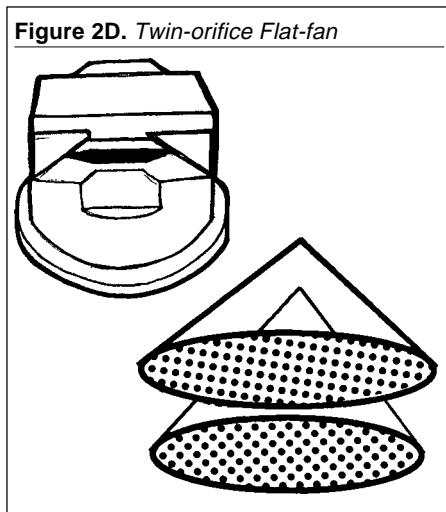
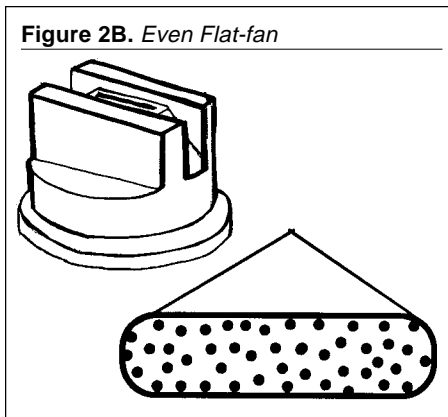
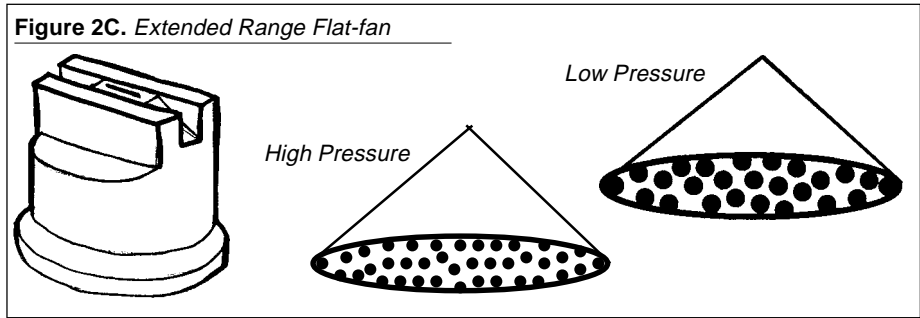
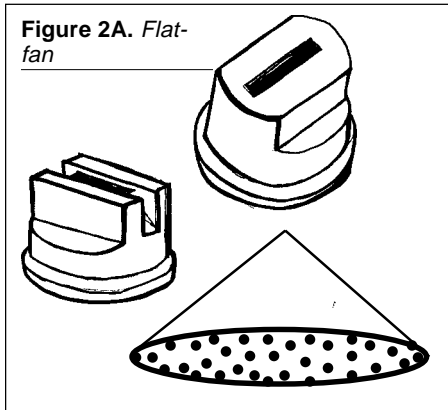
Hollow-cone nozzles (Figure 2F) generally are used to apply insecticides or fungicides to field crops when foliage penetration and complete coverage of the leaf surface is required. These nozzles operate in a pressure range from 40 to 100 psi. Spray drift potential is higher from hollow-cone nozzles than from other nozzles due to the small droplets produced. Generally, this type of nozzle should not be used to apply herbicides.

### Full-cone

The wide-angle, full-cone nozzles are a good choice if drift is a concern because they produce larger droplets than flood nozzles. Full-cone nozzles (Figure 2G) usually are recommended over flood nozzles for soil-incorporated herbicides.

Full-cone nozzles operate between a pressure range of 15 to 40 psi and are ideal for sprayers equipped with flow controllers.

**Relative droplet size for each spray tip is shown in patterns.**



Optimal uniformity is achieved by angling the nozzles 30 degrees and overlapping the spray coverage by 100 per cent.

**Fine Hollow-cone**

The Cone-Jet (Spray Systems) and WRW-Whirl Rain (Delavan) are wide-angle (80-120 degrees), hollow-cone nozzles. These nozzles are used for postemergence contact herbicides where a finely atomized spray is used for complete coverage of plants or weeds.

**Nozzle Materials**

Nozzles can be made from several materials. The most common are brass, nylon, stainless steel, hardened stainless steel, tungsten carbide, and ceramic. Ceramic and tungsten carbide nozzles are very long-wearing and extremely

corrosion-resistant. Stainless steel nozzles last longer than brass or nylon and generally produce a more uniform pattern over an extended time period. Nylon nozzles with stainless steel or hardened stainless steel inserts offer an alternative to solid stainless steel nozzles at a reduced cost. Thermoplastic nozzles have good abrasion resistance, but swelling can occur with some chemicals, and they are easily damaged when cleaned. Nozzles made from hard materials cost more initially, but in the long run, they pay for themselves because of long-lasting properties.

**Do not mix nozzles of different materials, types, spray angles, or spray volumes on the same spray boom.** A mixture of nozzles produces uneven spray distribution.

## Nozzle Screens

To prevent plugging and excessive wear of the nozzles, always use screens (Figure 3) to remove large particles from the spray mixture, except when spraying very large volumes. At low rates, use 100-mesh screens. When using higher rates or applying wettable powders, use the 50-mesh size; check the manufacturer's recommendations for the specific nozzle. Smaller mesh screens may plug more easily and therefore require more frequent cleaning. Some screens have a ball check valve to prevent drip when the sprayer boom is turned off (Figure 4). These are useful if you stop in the field since excessive residues may damage the current and/or succeeding crop.

Another available anti-drip device is a diaphragm check valve (Figure 5). This valve allows the nozzle tip to be changed without letting spray material leak from the boom. Also, the diaphragm helps to protect the device from chemical corrosion which could cause a check valve to fail.

## Nozzle Selection

It is important to select a nozzle that develops the desired spray pattern. The specific use of a nozzle, such as the broadcast application of herbicides or spraying of insecticides on row-crops, determines the type of nozzle needed. Examine current and future application requirements and be prepared to have several sets of nozzles for a variety of application needs. The steps below will help determine the correct nozzle type and capacity needed.

**Step 1: Consult the Label.** The most important source of information is the pesticide label. Not only will the label specify the application rates, controllable pests, and conditions needed to apply the pesticide, it often will provide information concerning the gallons per acre, nozzle type, and spacing. Follow the guidelines outlined by the pesticide label. If nozzle recommendations are not stated on the label, use Table II for selecting a type of nozzle to fit the application need.

**Step 2: Select Operating Conditions.** Select or measure ground speed in miles per hour (mph). If speed is unknown, follow the steps for calibrating a sprayer covered in this publication under *Sprayer Calibration With the "Ounce"*

*Method* or in ID-98, *Guidelines for Pesticide Use*, or AGR-6, *Chemical Control of Weeds in Kentucky Farm Crops*. Select the desired nozzle spacing and spray volume. For most broadcast applications, 20-inch spacing is preferred. If these are not given on the pesticide label, follow Kentucky Cooperative Extension Service and chemical company recommendations.

Correct selection of spray volume is important. It will influence several spray characteristics such as drift potential, the spray coverage, droplet size, acres per tank, and pesticide effectiveness. As a rule of thumb, the greater the operating pressure or the greater the spray angle, the smaller the droplets become. Smaller droplets increase the drift potential. As the nozzle orifice becomes larger, the droplets increase in size. Some manufacturers have "drift reduction" nozzles available, such as air induction or "drift guard" nozzles that create a larger droplet that is less prone to drift.

**Step 3: Calculate Required Nozzle Discharge.** To select a specific orifice size, the spray volume, nozzle spacing, and travel speed are needed for the following calculation:

$$\text{Nozzle Discharge (GPM)} = \frac{\text{Travel Speed} \times \text{Nozzle Spacing} \times \text{Spray Volume}}{5940}$$

where:

Travel Speed = miles per hour (mph)

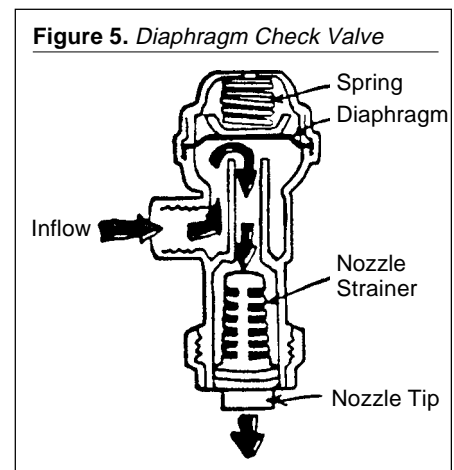
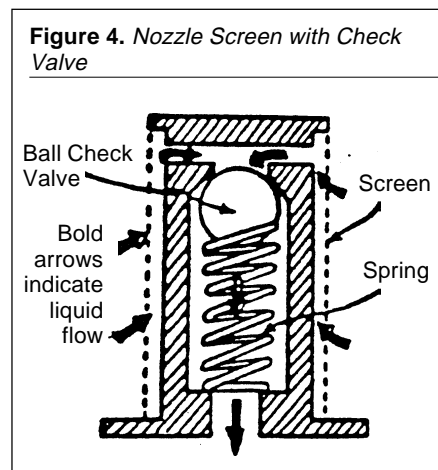
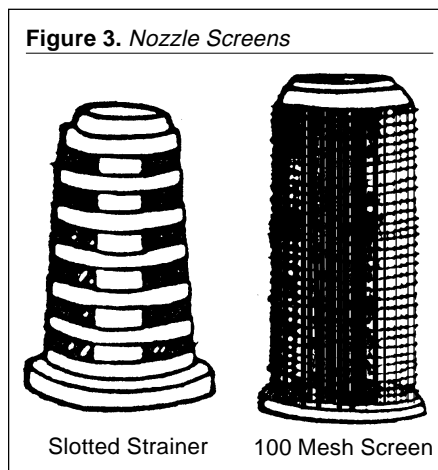
Nozzle Spacing = inches (in)

Spray Volume = gallons per acre (GPA)

### Nozzle Selection and Sizing Example:

Suppose a postemergence herbicide is to be broadcast at 15 GPA at a speed of 5 mph. From Table II, the "BEST" choice was an extended-range flat-fan. The recommended nozzle spacing is 20 inches. Calculate the required nozzle discharge:

$$\text{Nozzle Discharge} = \frac{5 \text{ mph} \times 20 \text{ in} \times 15 \text{ GPA}}{5940} = 0.25 \text{ GPM}$$



Figures 3 - 5 courtesy of the Northeast Regional Agricultural Engineering Service, Cornell University, Ithaca, N.Y.

The nozzle you select must have a flow discharge of 0.25 GPM when operated within the recommended pressure range from 15 to 60 psi (preferably under 40 psi). Nozzle performance tables in manufacturer's catalogs will show the discharge rates at various pressures for several nozzle sizes. Select the nozzle which will give you the most flexibility with a wide pressure range for "fine-tuning."

**Step 4: Consult the Nozzle Catalog.** Once the nozzle discharge (GPM) has been determined, consult the nozzle catalog for a specific nozzle number or size. Using the nozzle type selected from the application guide (Table II), review the specification of these nozzles in the discharge capacity column. Several consecutive nozzles may meet your need, but select a nozzle that operates at a low pressure and still gives a range for fine-tuning. Remember, most nozzles perform only over a limited pressure range.

A change in pressure does not cause an equal change in flow discharge. In some examples, in order to double the spray output, the pressure would have to be quadrupled. If you do not find the discharge rate in the catalogs, calculate the operating pressure using known catalog conditions:

$$psi_1 = psi_2 \times \left[ \frac{GPM_1}{GPM_2} \right]^2$$

where:

subscript "1" is the desired condition and  
subscript "2" is the known catalog condition

**Example:**







How much would the psi have to be increased to increase GPM from .26 to .40?

$$psi_1 = 30 \text{ psi} \times \left[ \frac{.40 \text{ GPM}}{.26 \text{ GPM}} \right]^2 = 30 \text{ psi} \times 2.37 = 71 \text{ psi}$$









Although some nozzles such as cone types require high operating pressures, try to avoid pressures above 40 psi. Pressures over 40 psi increase the drift potential and put strain on the sprayer components. Conversely, avoid pressures less than the recommended minimum pressure because spray patterns begin to distort and cause poor spray uniformity.

**Step 5: Calibrate the Sprayer.** Once the nozzles are selected, purchased, installed, and flushed, calibrate the spray system. Nozzle catalogs provide tables to show spray volumes for various nozzles, spacing, pressures, and ground speeds. Use these tables to initially set up the sprayer, then use the "ounce" calibration method to evaluate and adjust the sprayer for accurate application.







**Table II. Nozzle Recommendations**

	<b>Raindrop</b> 	<b>Hollow-Core</b> 	<b>Flooding</b> 
			
<b>Pre-Emerge Herbicides</b>			
Soil Incorporation	Good		Good
Band			
Broadcast	Good		Good
<b>Post-Emerge Herbicides</b>			
Contact-Band			
Contact-Broadcast		Good	
Systemic-Band			
Systemic-Broadcast	Good	Good	
<b>Insecticide</b>			
Band			
Broadcast			

	<b>Even Flat-Fan</b> 	<b>Twin Orifice Flat-Fan</b> 	<b>Extended Range Flat-Fan</b> 	<b>Standard Flat-Fan</b> 
				
<b>Pre-Emerge Herbicides</b>				
Soil Incorporation			Best	Better
Band	Best			
Broadcast		Good	Best	Better
<b>Post-Emerge Herbicides</b>				
Contact-Band	Best			
Contact-Broadcast		Better	Best	Better
Systemic-Band	Best			
Systemic-Broadcast			Best	Better
<b>Insecticide</b>				
Band	Best			
Broadcast		Good	Best	Better

	<b>Full-Cone</b> 	<b>Solid-Cone</b> 	<b>Fine Hollow-Cone</b> 
			
<b>Pre-Emerge Herbicides</b>			
Soil Incorporation	Best		
Band		Good	
Broadcast			
<b>Post-Emerge Herbicides</b>			
Contact-Band		Good	Good
Contact-Broadcast			
Systemic-Band			Good
Systemic-Broadcast		Good	
<b>Insecticide</b>			
Band			Best
Broadcast		Good	

## Sprayer Calibration with the “Ounce” Method

- 1. Use the chart below** for distance to drive in the field. Use nozzle spacing for booms. For directed and band rigs, use the row spacing.
- 2. Set throttle for spraying and operate all equipment.** Note seconds required to drive measured distance.
- 3. Catch spray for the noted time in Step 2** in container marked in ounces (a calibrated bottle or measuring cup). If boom, catch spray from one nozzle during noted time. On directed rigs, catch spray from all nozzles per row for noted time.
- 4. Nozzle or nozzle group output in ounces equals gallons per acre actually applied.**
- 5. Repeat for each nozzle** to assure uniform distribution.

Row Width or Nozzle Spacing (IN)	Distance (FT)	Row Width or Nozzle Spacing (IN)	Distance (FT)
44	93	28	146
42	97	26	157
40	102	24	170
38	107	22	185
36	113	20	204
34	120	18	227
32	127	16	255
30	136	14	291

## Replacing Nozzle Tips

Worn nozzles increase application rates and change distribution patterns. The result is poor pest control, crop damage, residue problems, and increased costs. A check of the boom sprayer assures that each tip is delivering an identical volume of spray in a smooth pattern with no heavy streams or blank areas. Should a nozzle become clogged, it is best to blow out the dirt with compressed air or use a soft-bristled brush such as a toothbrush. Wear chemically resistant gloves when handling and cleaning nozzles to reduce pesticide exposure. **NEVER** use a wire or nail as a cleaner because the orifice can be easily damaged. **NEVER** put tips in the mouth. Remember, improperly functioning or worn nozzles are costly.

## Manufacturers of Nozzles

There are two principal U.S. manufacturers of spray nozzles and accessories. Local spray equipment dealers probably handle one or more of these lines. Each manufacturer distributes nozzle catalogs. These can be obtained from the local dealer or ordered at the following addresses:

**Delavan-Delta, Inc.**  
4115 Corporate Center Dr.  
Monroe, NC 28110-1313  
800-621-9357

**Spraying Systems Co.**  
TeeJet (*home office*)  
North Avenue  
P.O. Box 7900  
Wheaton, IL 60189-7900

TeeJet Northeast (*branch office*)  
P.O. Box 397  
124A West Harrisburg St.  
Dillsburg, PA 17019  
717-432-7222

## Other Kentucky Extension Publications

- ID-98 *Guidelines for Pesticide Use*  
ID-100 *Understanding Pesticide Labels and Labeling*  
AGR-6 *Chemical Control of Weeds in Kentucky Farm Crops*  
IP-13 *Protecting Kentucky's Groundwater: A Grower's Guide*

## WEIGHTS & 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 kilometers per hour

### Volume

27 cubic feet = 1 cubic yard  
1 cubic foot = 1728 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

\* Mention of trade and company names are included for the benefit of the reader and do not imply endorsement or preferential treatment of the product by the University of Kentucky Cooperative Extension Service.

**Special thanks** are extended to Charles H. Slack, Department of Agronomy, and Lee H. Townsend, Pesticide Applicator Training Coordinator, Department of Entomology, University of Kentucky, for reviewing draft manuscripts. Also special thanks to George Duncan, Agricultural Engineering, for providing portions of the manuscript and for revision review.

Adapted from NebGuide G89-955, Cooperative Extension Service, University of Nebraska, written by Robert D. Grisso.

Educational programs of the Kentucky Cooperative Extension Service serve all people regardless of race, color, age, sex, religion, disability, or national origin. Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, C. Oran Little, Director of Cooperative Extension Service, University of Kentucky College of Agriculture, Lexington, and Kentucky State University, Frankfort. Copyright © 2000 for materials developed by the University of Kentucky Cooperative Extension Service. This publication may be reproduced in portions or its entirety for educational or nonprofit purposes only. Permitted users shall give credit to the author(s) and include this copyright notice. Publications are also available on the World Wide Web at: <http://www.ca.uky.edu>. Issued 8-1992, Revised 2-2000, 4000 copies, 10000 copies to date.