

## Chapter 9

### Application Basics

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The use of foliar fungicides in soybean production in the northcentral United States is a relatively new practice. Until recently, this practice has been limited to control of late-season diseases in soybean grown in the lower Mississippi River basin. Fungicides have been applied aerially at three to five gallons per acre (GPA) or by tractor-mounted or dedicated ground spray systems with application volumes of 10 to 15 GPA.

Successful control of late-season diseases has been based on delivery of fungicides into the upper crop canopy.

Although experience in Brazil and elsewhere suggests that existing spray technology is adequate for managing soybean rust, technology improvements are needed. Soybean producers and custom applicators should do everything possible to make sure that they are applying the amount of fungicide recommended into the proper location of the canopy. Too little fungicide will result in poor control and reduced yields, while too much wastes dollars and increases the risk of phytotoxic effects and/or environmental pollution.

Spraying the proper amount of fungicide on each acre of soybean is not enough to achieve effective soybean rust control. Effective management of soybean rust with fungicides depends on placing fungicides as deeply into the canopy as possible. This is because the

disease usually starts in the lower canopy and moves into the middle, then upper, canopy as the crop matures. Nozzle type, spray pressure, application volume, and application speed determine uniformity of deposition and penetration into the canopy. Proper nozzle orientation and overlap are also critical to achieve uniform spray deposition.

Spray technology is available that may help improve coverage of foliage, but it may cost more than conventional technology. Producers may need to modify existing spray equipment to optimize application of fungicides to full-canopy soybean. The cost of equipment modification is likely to vary widely, depending on the extent of modifications needed. For example, cost may be low if only the nozzles are being replaced. On the other hand, modification may be costly if boom reconfiguration is necessary. Some producers will need to purchase new spray equipment. For many good reasons, including economic, producers tend to be conservative when it comes to extensive equipment modifications or purchasing new spray equipment. Soybean rust may help to shift this tendency since the alternative to making the necessary equipment modifications, or purchasing new equipment, may be heavy crop losses — a bigger economic burden to producers.

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## Which Spray Equipment Configuration Is Likely to Provide the Best Defense Against Soybean Rust?

Even though several research projects have been conducted to learn more about the influence of various application parameters, unfortunately we DO NOT yet have sufficient efficacy data for soybean rust using different spray equipment under U.S. conditions and limitations. However, we DO have spray coverage data from several research projects dealing with other lower canopy soybean diseases, such as Sclerotinia stem rot. An important question in these research projects has been: Does good coverage correlate with efficacy? As it turns out, in most cases, there is a very strong correlation between coverage and efficacy.

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## How to Achieve the Best Coverage

There are basically two ways to increase coverage — reduce droplet size and increase carrier volume. Ideally, it is best to have as many small droplets hit the target as possible. Nozzles currently used in crop production (herbicide-glyphosate applications) tend to produce a large range of droplet sizes. Large droplets, which will help mitigate spray drift, may not provide good coverage.

Very small droplets lack the momentum needed to push into the canopy, and many have the potential to evaporate within a few seconds of being released from the nozzle.

Thus, for soybean rust control, everything possible must be done to utilize droplets approximately 200 to 300 microns in diameter. Be aware that droplets in this size range are prone to drift under windy conditions. This is an important consideration since drifting droplets will not have any energy to penetrate into the soybean canopy and, thus, may be wasted. Also many soybean rust fungicides are toxic to aquatic invertebrates and fish, so drift near water should be avoided.

Select a combination of nozzles and spray pressure that can deliver the desired amount of material in the required gallons per acre at the travel speed necessary to produce 200 to 300 micron droplets in a uniform pattern.

Two additional factors that influence canopy coverage are boom height and overlap. If the boom is too high, droplets are more susceptible to movement by wind. Lowering the boom reduces the risk of drift during application, but doing so may also reduce the overlap required to provide adequate uniformity across the target. Overlap is needed to prevent skips between nozzles and to even out non-

Spray Angle	20-inch spacing	30-inch spacing
65 degrees	22 to 24 inches	33 to 35 inches
80 degrees	17 to 19 inches	26 to 28 inches
110 degrees	16 to 18 inches	20 to 22 inches
120 degrees	14 to 16 inches	15 to 17 inches

Table 9.1. Suggested minimum spray heights for given angles.

uniform spray patterns. With flat-fan nozzles, the outer edges of the spray pattern have reduced volumes. Overlapping adjacent patterns along a boom achieves more uniform coverage. On a broadcast sprayer, nozzle spacing and boom height determine overlap. When the spray boom is raised, overlap increases; when the spray boom is lowered, overlap decreases. Table 9.1 shows recommended minimum mounting heights for common fan angles and nozzle spacing.

### An Alternative to a Conventional Sprayer

In spray coverage tests conducted in Ohio, air-assisted sprayers consistently provided the best coverage of paper targets placed inside the crop canopy. This advantage was even more pronounced when spray deposits were evaluated on the undersides of leaves. Thus, air-assisted sprayer technology may be a viable option in soybean rust management programs. Unfortunately, a commercial-scale sprayer with the air assistance may add from \$10,000 to \$15,000 to the price of the equipment. Still, this expense may be worth the investment.

### Other Options

The density of the soybean foliage will definitely affect spray penetration into the canopy. Narrow-row plantings typically create denser canopies, and canopies become more dense during the reproductive stages. The density of the canopy will also be greatly influenced by the environmental conditions during the growing stages of the soybean crop.

If soybean is planted in a row, and there is sufficient clearance between rows at the time of spraying, some producers may opt to take advantage of directed spraying to cover the plant with more than one nozzle from different angles (from top and both sides) or with drop pipes between the soybean rows with a double swivel nozzle to the ends of these pipes, which extend between soybean rows. The spray from each nozzle should then be directed toward a row of soybeans. An additional nozzle can be placed on the boom and positioned directly above the row (Figure 9.1). These options are not always practical in heavy canopied soybean.

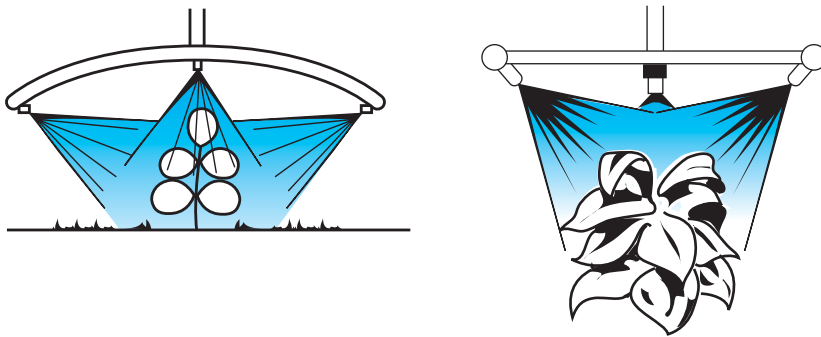


Figure 9.1. Spraying with nozzles attached at different angles to promote thorough coverage.



Figure 9.2. Different spraying systems used for fungicide applications with types of twin-pattern nozzles: Twin jet®, Turbo Duo®, Hypro Twin-cap® and Turbo TwinJet®.

## Droplet Size Will Influence Coverage

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, the American Society of Agricultural and Biological Engineers (ASABE) 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.

Currently, nozzle manufacturers recommend high-fine to mid-medium spray droplets (approximately 200 to 300 microns) for application of fungicides for soybean rust control. Since most nozzle sizes will span a range of droplet sizes dependent on the operating pressure, it is important to select the option that closely matches the high side of the fine category and the low to medium side of the medium category. This should approximate the 200 to 300 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. This last step, matching the droplet size, is not something familiar to most applicators today. It will be necessary to add this step to the set-up of the sprayer to optimize the fungicide application for increased lower canopy coverage and minimized drift.

### Selecting Nozzle Type

Always select the most appropriate nozzle to achieve the desired coverage and penetration. Nozzles producing a cone pattern are not recommended for soybean rust control because they produce a higher portion of very fine (less than 100 micron) droplets than flat fan nozzles at any given pressure. Flat-fan pattern nozzles are generally the best choice, provided the spray from these nozzles is categorized as high-fine to mid-medium.

### Determining Desired Droplet Spectra

Consulting the nozzle manufacturer’s droplet sizing charts is ESSENTIAL. Also, web sites and manufacturer’s literature are available to 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 (see Table 9-2).

A flat-fan nozzle setup with two spray patterns (twin orifice or twin outlet — see Figure 9.1) has been considered a good option to provide better coverage of plants with fully developed canopies. Some manufacturers have nozzles that provide a twin spray pattern from one tip, or special fittings or caps that allow the producers to place two nozzles in the same cap, one pointed forward, and the other one pointed backward.

However, recent research has shown that hitting the target (lower canopy) from

ASABE Standard S-572 Spray Quality Categories	
Category	Color
Very Fine (VF)	red
Fine (F)	orange
Medium (M)	yellow
Coarse (C)	blue
Very Coarse (VC)	green
Extra Coarse (EC)	white

	PSI										
	15	20	25	30	35	40	50	60	70	80	90
TT11001	C	M	M	M	M	M	F	F	F	F	F
TT110015	C	C	M	M	M	M	M	M	F	F	F
TT11002	C	C	C	M	M	M	M	M	M	M	F
TT11003	VC	VC	C	C	C	C	M	M	M	M	M
TT11004	XC	VC	VC	C	C	C	C	C	M	M	M
TT11005	XC	VC	VC	VC	VC	C	C	C	C	M	M
TT11006	XC	XC	VC	VC	VC	C	C	C	C	C	M
TT11008	XC	XC	VC	VC	VC	VC	C	C	C	C	M

Table 9.2. American Society of Agricultural Engineers (ASAE) Standard S-572 Spray Quality Categories.

two different angles, with one forward and one backward spray pattern, has not necessarily provided more effective coverage compared to spraying with just one spray pattern, shooting nearly straight down. In fact, the nozzle configurations with wider angles between the two outlets tended to provide the least amount of spray coverage in the lower canopy when foliage was dense.

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### A Calibration Example

Even though coverage may not be as good in some twin orifice or twin outlet nozzle configurations, the use of two nozzles in one cap gives the applicator more flexibility to achieve the higher application volumes and the droplet spectrum suggested for improved lower canopy coverage. As an example, for a single nozzle application, to achieve 20 GPA at 10 MPH with a 20-inch nozzle spacing, an “06” orifice (*i.e.*, TT11006) would be required to deliver a 0.67 GPM flow rate (20 GPA x 10 MPH x 20-inch nozzle spacing divided by 5,940). The pressure for this orifice scenario (TT11006) would need to be 50 PSI, resulting in a coarse droplet with some nozzle types and a medium droplet with the other options. If a double nozzle cap is used, then two TT11003 nozzles combined would meet the calibrated flow rate with the pressure still at 50 PSI. However, the smaller orifices would

produce smaller droplets (see Table 9.2). Again, depending on nozzle type, borderline medium/coarse or borderline medium/fine droplets are possible. The medium/fine option would be very close to the desired specifications for successful coverage in the soybean canopy.

Carefully reviewing the manufacturer’s flow rate and droplet category charts would reveal several other nozzle options acceptable for fungicide applications as long as the 200 to 300 micron size requirement is followed. For instance, in the previous example, the XR11006 nozzle at 50 PSI (0.67 GPM) would deliver a medium-sized droplet. The XR11005 nozzle at 58 PSI (0.67 GPM) would deliver a medium to fine droplet. Both would be possible choices. However, a TT11006 nozzle at 50 PSI (0.67 GPM) would deliver coarse to very coarse droplets. This would not be a good option. A TT11005 nozzle at 58 PSI (0.67 GPM) would also deliver coarse droplets, while a TT11004 nozzle at 95 PSI (0.67 GPM) would produce medium droplets and, thus, is a possible selection, provided the spray system can achieve and maintain operation at this high pressure.

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### Benefit of Increasing the Spray Volume

Studies have shown that 10 to 15 GPA application volumes

and a single outlet flat-fan nozzle can provide adequate canopy coverage as long as proper droplet size and pressure are used. However, as the crop continues to grow and there is more canopy cover, higher spray volumes will be needed. This is illustrated by Figures 9.3 and 9.4, which show two cards that were placed in the canopy during application. These cards, which were placed in the mid-canopy, registered a similar total deposition.

The spray coverage shown on the card in Figure 9.3 resulted from 10 GPA applied with a single turbo flat-fan nozzle, while the soybean plants were in the R2 growth stage. Achieving a similar coverage at the R5 growth stage as shown in the card in Figure 9.4 required 20 GPA. A twin orifice nozzle

(TwinJet) was used for this application.

Note that similar coverages were measured at the two spray volumes resulting from using two different nozzle types. Both nozzles, however, produced a similar range of droplet distribution; nearly 90 percent of the spray volume in both cases was delivered in droplets around the optimal 200 to 300 micron droplet size range.

In summary, coverage is critical for effective soybean rust control using fungicides. Spray volumes at 10 GPA may give acceptable results early in the season with less canopy density, but higher spray volumes will be required as the season progresses because the canopy is deeper and denser.

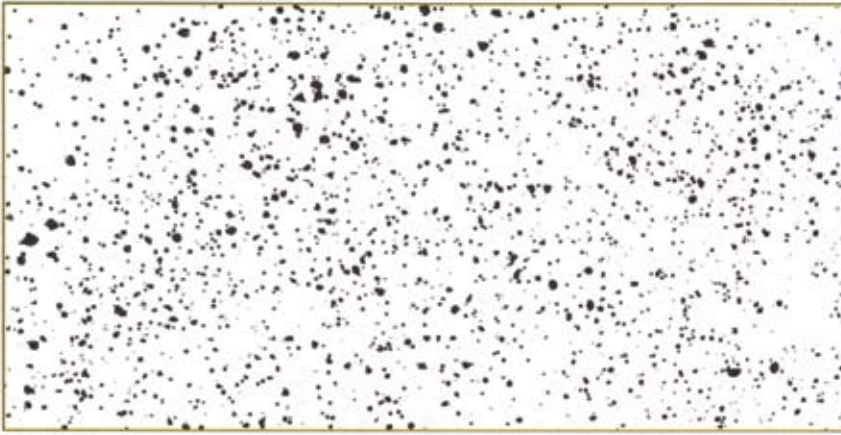


Figure 9.3. This indicator paper shows a volume median droplet size of 250µ. Nearly 90 percent of the total spray volume was delivered in droplets in the desirable size range. This pattern resulted from a ChromeCoat paper in the mid canopy of R-2 soybeans in South Dakota with 10 gpa delivered through a Turbo TeeJet (TT110015) nozzle at 7 mph and 50 psi.

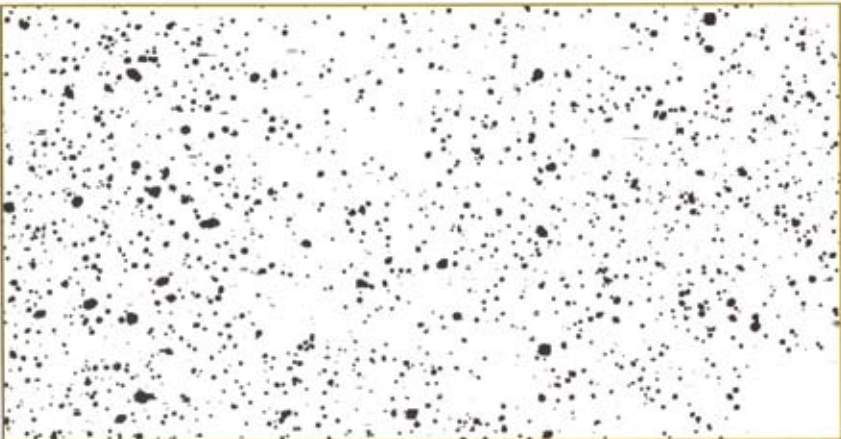


Figure 9.4. This indicator paper shows a volume median droplet size of 255µ. Nearly 85 percent of the total spray volume was delivered in droplets in the desirable size range. This pattern resulted from a ChromeCoat paper in the mid canopy of R-2 soybeans in South Dakota with 20 gpa delivered through a TwinJet (TJ60-11004) nozzle at 7 mph and 50 psi.

### Environmental Conditions Impact Application

Environmental conditions during fungicide application influence the final spray outcome. Applications made when temperatures exceed 90°F

and/or when humidity is low (<50 percent) may result in excessive evaporation of smaller droplets as they leave the nozzle. Another concern is the existence of in-crop microinversions. An in-crop microinversion may occur when high ambient temperatures are present

above the canopy, and cooler temperatures are present in the upper portions of the canopy. The lower temperature in the upper canopy results from the cooling effect of the dense canopy compared to the intense heat of the sunlight above the canopy (the shade affect).

Though not fully documented, some believe the microinversion may prevent smaller spray droplets from entering the canopy, especially from higher application releases. Also, spraying during windy conditions should be avoided due to drift concerns. Finally, foliage should be dry at the time fungicides are applied. Moisture on foliage (dew or rain) could reduce product efficacy due to dilution or runoff. Serious limitations in individual and system-wide spray capacities may make it necessary to spray some fields during less than ideal conditions. Nonetheless, best control of soybean rust is likely to be achieved when fungicide applications are made as close to ideal conditions as possible.

### Summary

- Choose the appropriate size and type of nozzle and operate at a pressure that will allow the creation of high-fine to mid-medium (200 to 300 micron) size droplets.
- When spraying in fields with shorter/less dense

canopies, the use of twin nozzle technology — two nozzles angled forward and backward — may work better than single nozzles spraying down. A single pattern flat-fan nozzle calibrated to achieve the proper application volume at a higher pressure may be just as successful or better, especially as the density in the canopy increases.

- Air-assisted spray systems may provide the best coverage and droplet penetration into full-canopied soybean. Energy from the air-assist system tends to move the canopy, exposing lower leaves. To achieve the best results, high pressures may be required.
- Keep spray volumes (application rate) at a minimum of 15 GPA for ground application and 5 GPA for aerial application, especially late in the growing season. Higher volumes may be necessary as the soybean crop density increases.
- Environmental conditions at the time of spraying can have a great influence on final disease control outcome.

### To spray fungicides for soybean rust:

- **Choose nozzles and adjust pressure to develop hi-fine to mid-medium spray quality (200 to 300 microns).**
- **Use higher spray pressure to achieve the desired droplet size.**
- **Flat-fan nozzles work as good or better than cone nozzles with less drift.**
- **Single pattern flat-fan nozzles work as good or better than double outlet or twin-nozzle configurations, especially in heavier canopy.**