

# Evaluation of various spraying equipment for effective application of fungicides to control Asian soybean rust

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(Summary of a research conducted at the Ohio State University in 2005)  
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## **Summary**

Fungicides manufactured to control soybean rust are effective; however, successful control of this disease will mostly depend on proper application methods. Spray coverage and deposition from 9 application equipment/spray nozzles were analyzed. In general, the spray treatments with air assistance were more effective in spraying rust fungicides than the treatments with the conventional boom sprayer. Spray performances from the boom sprayer with a canopy opener were very similar to the air assisted spray treatments, and were better than other treatments with the boom sprayer. Twin jet, Turbo Dual pattern and hollow cone nozzles produced lower spray performances than conventional flat fan nozzles. For treatments with the boom sprayer, medium spray quality provided higher spray coverage inside canopies than coarse and fine spray qualities. Future research will address how much fungicide inside canopies can be sufficient to control the soybean rust disease.

## **Introduction**

Soybean rust usually shows its first symptoms in the lower parts of the plant and works itself up towards the top of the plant. So, by the time producers notice the problem in the mid to upper canopy, it may be too late to spray any fungicide. Penetrating droplets inside the canopy of a fully grown plant is a much bigger challenge for soybean producers than the challenge they face for control of weeds and insects. Therefore spraying recommendations given for controlling weeds and some insects are not applicable to spraying for rust fungicides. Unfortunately the fungicide labels fail to clearly state the spray equipment and methods that are best suited for application of rust fungicides.

The principal objective of this study was to determine the most effective spray equipment and methods for applying fungicides to soybeans to control Asian Soybean Rust. Questions asked frequently by the soybean growers that were addressed in this study are: What is the best a) nozzle type (cone, flat-fan, low-drift, etc.), b) droplet size range, c) spray pressure, d) nozzle setup (twin pattern, single nozzle), and e) sprayer setup (conventional, air-assisted).

## Materials and Methods

The research was conducted in a soybean field located at ATI (Agricultural Technical Institute) of the Ohio State University / Ohio Agricultural Research and Development Center in Wooster, Ohio. The variables related to nozzles/equipment included in this study were: a conventional boom sprayer with three conventional nozzles (flat fan, cone, twin-flat fan) and a low-drift nozzle (turbo TeeJet Duo) manufactured by Spraying Systems Co. (Wheaton, IL, USA); an air-assisted sprayer; a pre-mixed air and liquid sprayer (AirJet); and an experimental boom sprayer called “canopy opener” equipped with conventional XR Flat-fan nozzles.

A second component of the study was to determine the effect of spray quality (fine, medium, coarse) on spray deposition and coverage using three different sizes (8002, 8004 and 8005) of XR type of a flat fan nozzle operated at different spray pressures. The application rate was kept constant at 15 gal/acre for all the treatments. Table 1 gives detailed information on the variables included in this study. A control plot was added to the experiment. Each plot was 150 ft long and 15 ft wide. Each treatment was replicated 4 times.

Table 1. *Nozzles, sprayers and operating conditions used in field soybean rust spray tests*

Treatment		Pressure	Speed	Flow	Spray
Sprayer	Nozzle	(psi)	(mph)	(gal/min)	quality
Air-assisted	Hollow cone JA3	154	7	0.35	fine
AirJet	Air & liquid pre-mixed	†	7	0.35	medium
Boom sprayer	Flat fan XR8004	31	7	0.35	medium
Boom sprayer	Flat fan XR8002	42	4	0.20	fine
Boom sprayer	Flat fan XR8005	20	7	0.35	coarse
Boom sprayer	Turbo TeeJet Duo	31	7	0.35	medium
Boom sprayer	TwinJet60-8004	31	7	0.35	medium
Boom sprayer	Hollow cone TX-18	54	7	0.35	fine
Boom sprayer with canopy opener	Flat fan XR8004	31	7	0.35	medium

† Liquid pressure = 42 psi, air pressure = 27 psi.

The air-assisted sprayer used in this study was the Jacto Model Advance 3000 pull type agricultural sprayer (Jacto, Pompeia, SP Brazil). It had a 60 ft long air bag along the entire length of the boom. The nozzles were located just behind the narrow air outlet which ran the entire length of the boom. The air jet was delivered at 58° angle toward the liquid spray pattern which had a vertical direction toward the soybean canopy. Nozzles were hollow cone JA3 nozzles (Jacto, Pompeia, SP Brazil ) mounted 4 in. behind the air jet outlet and were operated at 154 psi.

The canopy opener consisted of a 12 ft long conduit pipe with 1.25 inch outside diameter. The conduit was mounted 22 inches below and 10 inches ahead of the nozzles to open up the canopy as the sprayer travelled to achieve better penetration of spray into lower parts of the soybean plant, where the rust infection first starts. Only the flat fan XR 8004 nozzles were used for the test with the canopy opener.

The AirJet sprayer was the Top Air model TA 1600 T-tank sprayer (Unverferth Equipment Co., Alliance Product Group, Kalida, OH). With the AirJet atomizer, the air and liquid are mixed in a chamber before being discharged from the nozzle orifice. The sprayer was operated at 42 psi for liquid pressure and 27 psi for air pressure.

The conventional boom sprayer consisted of a gasoline engine-driven diaphragm pump, a 53 gallon water tank, and a 12 ft-long spray boom, and was supported with a three-point hitch behind the tractor. The spray boom was equipped with 7 nozzles, and was mounted on the right side of the tractor. The first nozzle was 20 inches away from the tractor rear tire, and nozzles

were spaced 18 inches apart. The boom height could be adjusted from 43 to 67 inches above the ground. Nozzles tested with the boom sprayer (Table 1) were: three conventional flat fan nozzles (XR8002, XR8004 and XR8005) representing fine, medium and coarse spray qualities; a twin pattern nozzle (TwinJet60-8004); a dual nozzle (Turbo Duo) containing two pre-orifice Turbo TeeJet flat fan tips (QJ90-2XTT11002); and a hollow cone nozzle (TX-18). The Turbo Duo nozzle was a two-tip assembly that produced two flat patterns; one at 45° angle forward, and the other at 45° backward from the sprayer travel direction. All nozzles are manufactured by Spraying Systems Co. (Wheaton, IL).

Effectiveness of the variables listed above for control of soybean rust was determined using three different methods: a) spray coverage on water sensitive papers, b) spray deposition on metal artificial targets using a spray solution mixed with a tracer, and c) fungicide spray deposition on actual soybean leaves. Samples for these tests were taken at two plant heights: lower and middle parts of the canopy. For spray coverage and tracer deposit studies, targets were arranged so that the quantity of potential spray deposit and coverage on both under side and upper side of leaves could be determined. The plots were also sprayed with the rust fungicide HEADLINE, containing 23.6% pyraclostrobin (BASF company, Ludwigshafen, Germany) at the recommended dose of 6 oz/acre. After spraying the plots with the fungicide, samples of leaves and stems were collected from the middle and lower part of the canopy to determine the amount of actual fungicide deposits on leaves and stems using a gas chromatography mass spectrometer. (The analysis of the fungicide samples has not been completed at this time - results will be made available when the analysis is completed).

The experiment was conducted when soybeans were at R5 growth stage with a height of approximately 38 in. It was planned to conduct an evaluation of efficacy level of the fungicide for control of soybean rust. This part of the study was not done because the field where this study was conducted did not have any soybean rust disease.

Three stakes holding artificial targets were placed 56, 75 and 95 ft from the beginning edge of each plot. The artificial targets were 1" x 3" sheet metal plates and 2" x 3" water sensitive papers. The sheet metal plates were used to collect spray deposits inside the canopy while water sensitive papers were used to determine spray coverage on both upper and lower sides of leaves. The artificial targets were positioned at 1 ft and 2 ft above the ground, representing the bottom and middle parts of the canopy (Fig. 1), respectively. For the middle stake in each plot, two plates were used to collect spray deposits at each height. For the other two stakes and at each height, two plates were separately used to collect spray deposits, two water sensitive papers were separately used to determine the spray coverage on the upper side of leaves and another two water sensitive samples were used to determine the spray coverage on the lower side of leaves. The artificial targets were mounted horizontally with their longer dimension normal to the stake and with 90° radial separation from each other at each height.

The application rate for all treatments was adjusted by either travel speed or flow rate to achieve 15 gal/acre (Table 1), and nozzle height for all treatments was set at 12" above the top of the canopy. A spray mixture containing water and Brilliant Sulfaflavine (MP Biomedicals, Inc., Aurora, OH) at a concentration of 7.5 grams/gal was used for all treatments. Each treatment was repeated four times in four 150 ft long and 15 ft wide plots containing R5 stage soybean plants.

The artificial targets were collected 5 minutes after spraying. The plates were stored in 125-ml wide-mouth glass bottles in non-transparent boxes. The water sensitive papers were stored in plastic sandwich bags. Spray deposits on metal plates were washed and dissolved in 0.68 oz. of purified water. Then, a 0.14 oz. sample solution was placed in a cuvette for determination of peak fluorescent intensity with a Model LS 50B Luminescence Spectrometer (Perkin-Elmer Limited, Beaconsfield, Buckinghamshire, England) at an excitation wavelength of 460 nm. Spray deposits on plates were then converted to a percentage of the 15 gal/acre spray application rate.

The spray coverage on each water sensitive paper was analysed with a computer imaging system which includes a desktop computer, an HP Scanjet 5530 photo-smart scanner and an image software *Image Tool*.

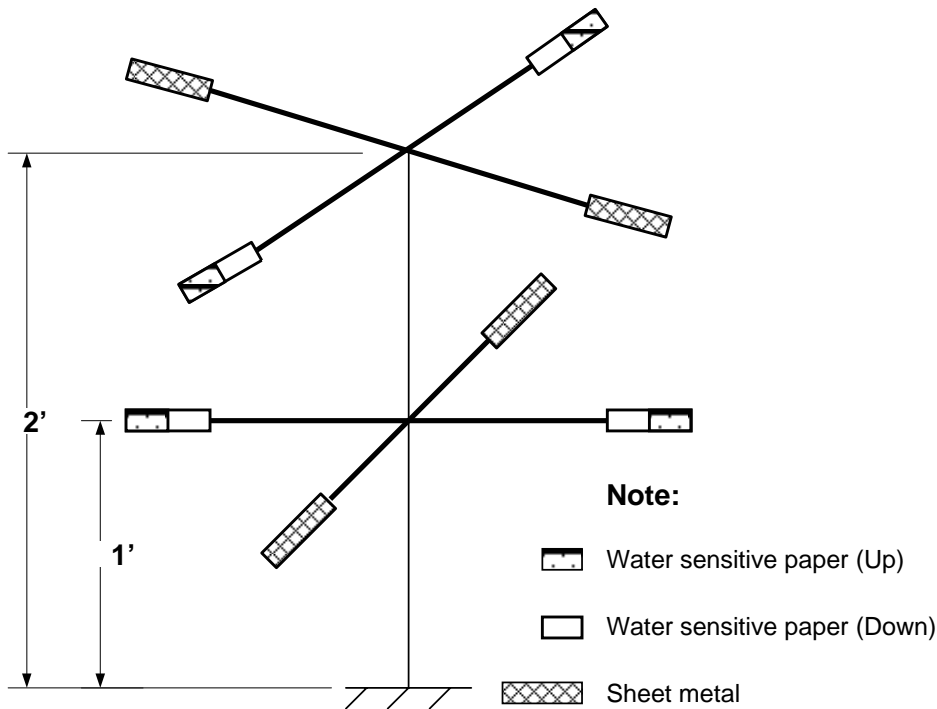


Fig. 1. Positions of artificial targets inside soybean canopies

Except for the AirJet sprayer, droplet sizes and velocities from nozzles used in the tests were measured with the VisiSizer particle/droplet laser image analysis system (Oxford Lasers, Oxfordshire, UK). Droplet size distributions and velocities were determined 12 in. below the nozzle orifice across the centreline of the spray pattern width. The nozzles evaluated with the boom sprayer produced values of volume median diameter (VMD) in the order from smallest to largest as hollow cone, XR8002, TwinJet60-8004, XR8004, Turbo Duo, and XR8005.

Following the measurement of spray deposition and coverage inside the canopy, leaf area index (LAI) of the soybean canopy was determined using an LAI-2000 plant canopy analyzer (LI-COR<sup>®</sup>, Inc., Lincoln, Nebraska) with two sensor modes. Three small sections in each plot were randomly selected for the LAI measurement. For each small section, four measurements of LAI at four orientations in a square shape were conducted. The sky was fully covered by clouds at the moment of measurement. The LAI sensor was also calibrated under fully-cloudy conditions.

For the air assisted sprayer, air velocities at four different locations near the air outlet, and at four different points 13 in. below the air outlet were measured with an air velocity meter (Model 8386A, TSI Inc., St. Paul, MN). The measurement points were evenly distributed across the boom length. The air velocity at each point was measured four times. The average air speeds near the air outlet, and 13 in. below the nozzle were 109 ft/s and 32 ft/s, respectively.

## Results and Discussion

In general, the spray treatments with air assistance were more effective in spraying rust fungicides than the treatments with the conventional boom sprayer in terms of percent coverage and deposit. Spray performances from the boom sprayer with a canopy opener were very similar to the air assisted spray treatments, and were better than other treatments with the boom sprayer. Twin jet, Turbo Dual pattern and hollow cone nozzles produced lower spray performances than conventional flat fan nozzles. For treatments with the boom sprayer, medium spray quality provided higher spray coverage inside canopies than coarse and fine spray qualities.

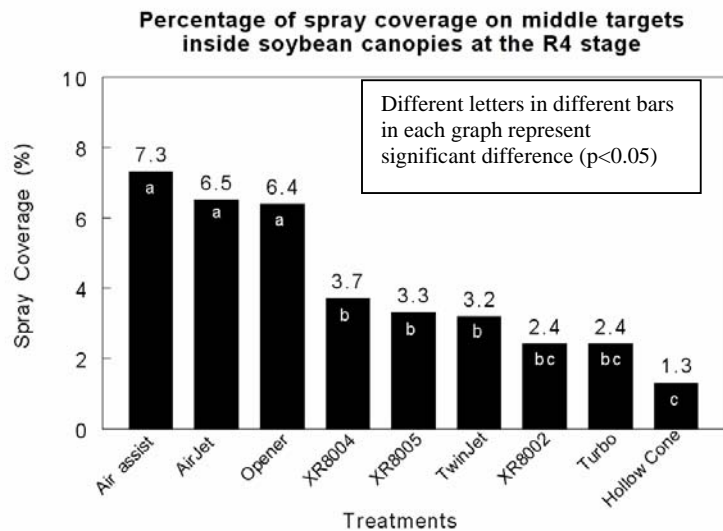
Results are presented in figures 2-5. Different letters in different bars in each graph represent significant difference ( $p < 0.05$ ).

### Spray Coverage

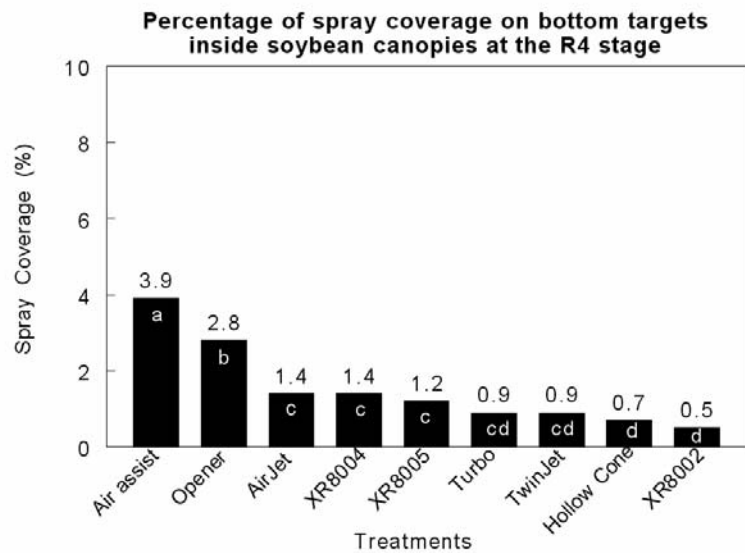
The average spray coverage at the middle part of the soybean canopy (or 2 ft above the ground) varied from 1.3 to 7.3% among the 9 treatments (Fig. 2(a)). The air-assisted sprayer provided the highest spray coverage at the middle part of the canopy, followed by AirJet sprayer and the boom sprayer with the canopy opener. The boom sprayer with TX-18 hollow cone nozzles produced the lowest spray coverage at the middle part of the canopy, followed by Turbo duo, and then XR8002 nozzles.

The average spray coverage at the bottom part of the soybean canopy (or 1 ft above the ground) varied from 0.5 to 3.9% among the 9 treatments (Fig. 2(b)). Similarly to the coverage at the middle part of the canopy, the air-assisted sprayer provided the highest spray coverage at the bottom part of the canopy, followed by the boom sprayer with the canopy opener and then the AirJet sprayer. The boom sprayer with XR8002 nozzles produced the lowest spray coverage at the bottom part of the canopy, followed by hollow cone TX-18 nozzles. XR8002 flat fan nozzles and hollow cone nozzles had smaller droplets than other treatments with the boom sprayer.

Compared to the boom sprayer with XR8004 nozzles, the canopy opener increased spray coverage at both middle and bottom parts of the canopy (Figs. 2 (a) and 2(b)). At the growth stage R3 to R5, most soybean leaves were at the top part of plants and these leaves covered most area of the field. The average leaf area index of the soybean canopy at the time the experiments were conducted was 6.4. With such high canopy density, most spray droplets from nozzles were intercepted by the top leaves.



(a)



(b)

Fig. 2. Comparison of spray coverage on (a) the middle targets and (b) bottom targets inside soybean canopies among the 9 treatments.

With the help of the pipe on the canopy opener pushing the top part of the canopy forward and down, a higher spray deposition and coverage were achieved on targets at both middle and bottom parts of the canopy.

Among the three spray qualities (fine, medium and coarse), the medium quality spray provided the highest coverage and the fine quality spray provided the lowest coverage at both middle and bottom parts of the canopy (Figs. 2(a) and 2(b)).

Compared to the XR8004 flat fan pattern nozzles with medium spray quality, Twinjet, Turbo dual pattern nozzles and hollow cone nozzles provided very low coverage at the middle and bottom parts of the canopy. Droplets from Twinjet, turbo dual pattern nozzles and hollow cone nozzles had poor penetration capabilities because these droplets had horizontal velocities. The horizontal movement of droplets consumed kinetic energy and caused droplets to easily settle on the top leaves. Also, the resultant droplet velocities from the three nozzles were lower than the velocity from XR8004 nozzles. To increase the droplet penetration capability, all kinetic energy of a droplet should be used for increasing its vertical velocity. Therefore, with the same application rate, twin fan pattern nozzles could not perform the same spray delivery efficiency as other conventional fan pattern nozzles.

**Droplet density**

Figures 3(a) and 3(b) show the average number of droplets per square centimeter on water sensitive papers at middle and bottom parts of the canopy. The Jacto air assisted sprayer, perhaps because of the smaller droplets it was discharging, provided a much greater number of droplets on the targets than any other treatments. With the same operating conditions, the boom sprayer with the canopy opener had a greater number of droplets on the targets inside canopies than other treatments with the boom sprayer. The treatment with Turbo Duo nozzles, due to its larger droplet sizes and lower droplet velocity, had the lowest number of droplets deposited on targets both at middle and bottom parts of the canopy.

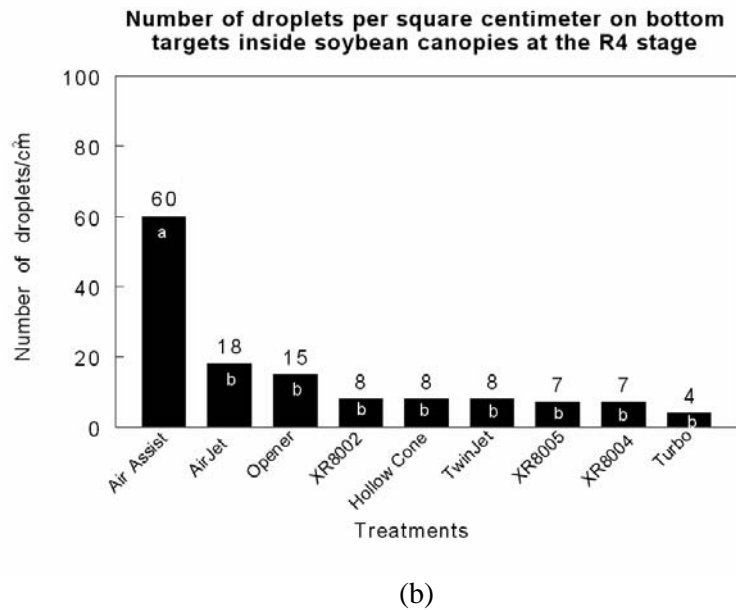
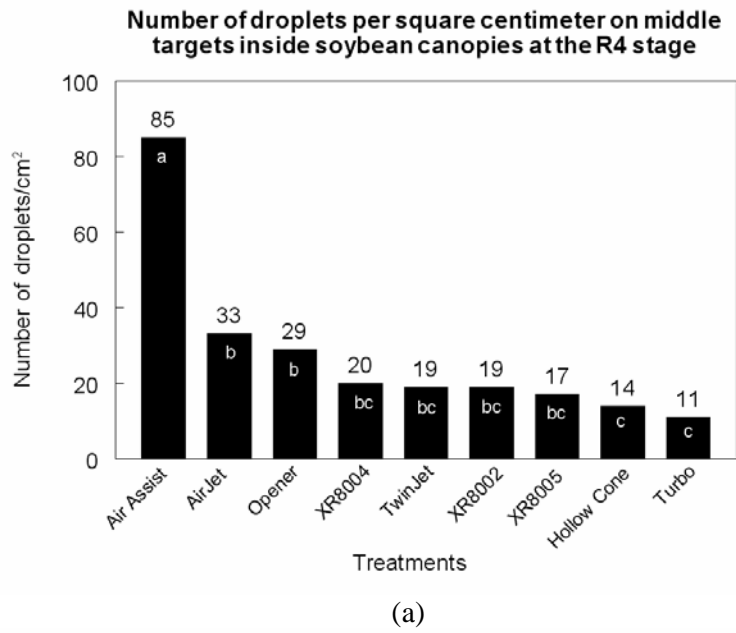


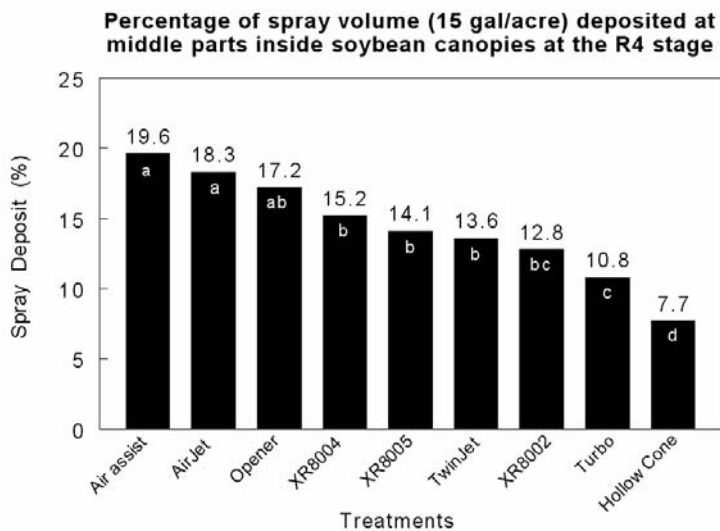
Fig. 3. Comparison of number of droplets per cm<sup>2</sup> on (a) the middle targets and (b) the bottom targets inside soybean canopies among the 9 treatments.

## Spray Deposits

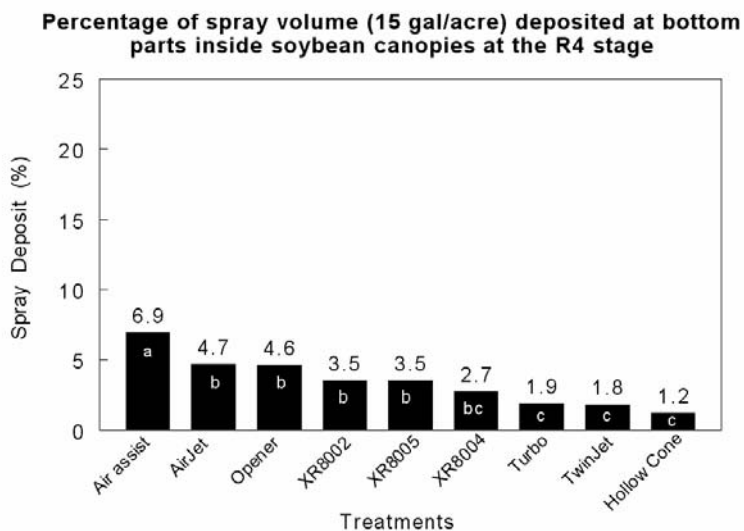
The average spray deposits in the middle of the canopy (or 60 cm above the ground) varied from 7.7 to 19.6% of the application rate among the 9 treatments (Fig. 4(a)). The air-assisted sprayer produced the highest spray deposits at the middle part inside canopies, followed by the AirJet sprayer and the boom sprayer with the canopy opener. The boom sprayer with hollow cone nozzles produced the lowest spray deposits at the middle part inside canopies, followed by Turbo Dual pattern and then XR8002 nozzles.

The average spray deposits at the bottom part of soybean canopies (or 1 ft above the ground) varied from 1.2 to 6.9% of the application rate among the 9 treatments (Fig. 4(b)). Similarly to the deposition at the middle part of the canopies, of the 9 treatments, the air assisted sprayer provided the highest spray deposition at the bottom part inside canopies, followed by the AirJet sprayer and the boom sprayer with the canopy opener. The boom sprayer with hollow cone nozzles produced the lowest spray deposition at the bottom part inside canopies, followed by TwinJet and then Turbo dual pattern nozzles. The slower travel speed of the XR8002 nozzle treatment (fine spray quality) may have helped it achieve greater penetration and produce higher deposits in the bottom part of the soybean canopy compared to the other six conventional sprayer treatments.

Compared to the boom sprayer with XR8004 nozzles, the canopy opener increased spray deposits at both middle and bottom parts inside canopies (Figs. 4). As mentioned earlier, the average leaf area index determined from the sample leaves collected from the field was 6.4. With such high canopy density, most spray droplets from nozzles were intercepted by top leaves. With the help of the canopy opener to push the top part of canopies, spray droplets would have more space to reach middle and bottom canopy levels, resulting in higher spray deposits in those locations.



(a)



(b)

Fig. 4. Comparison of spray deposits on (a) the middle targets and (b) the bottom targets inside soybean canopies among the 9 treatments.

## Conclusions

Spray trials were conducted in a soybean field that had higher than normal canopy height and denser than normal canopy density. Therefore, under different canopy height and density conditions some of the nozzles which did not perform well may outperform other nozzles under different canopy conditions. Following is a list of specific conclusions emerged from this study:

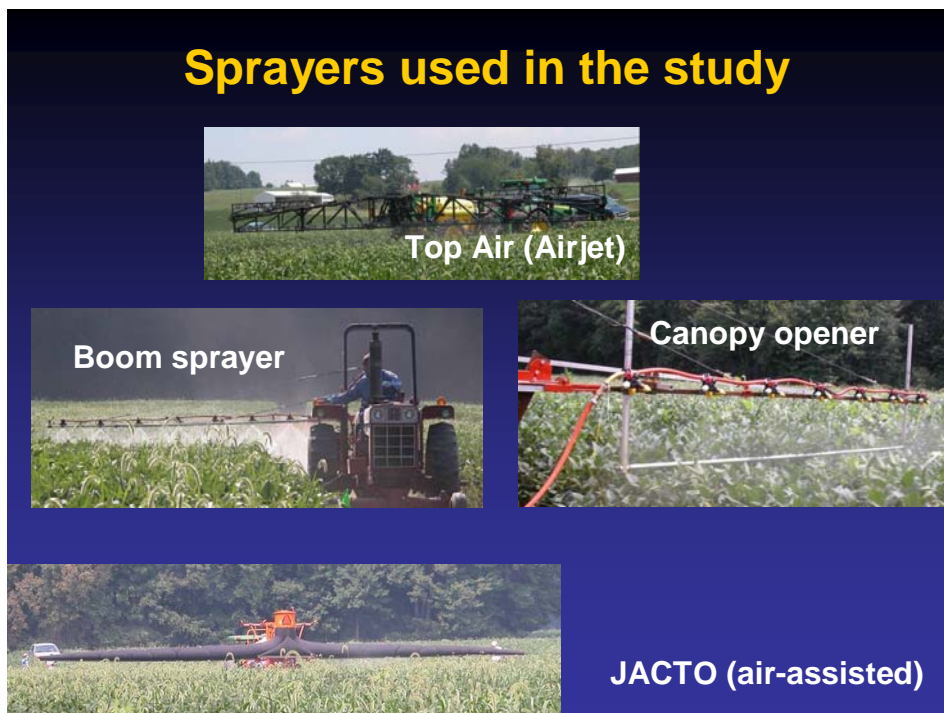
1. When using conventional sprayers, nozzles / equipment set up that provide medium spray quality (rather than fine or coarse) tend to provide a better penetration of droplets inside canopy and better coverage.
2. Spray hitting the target from two different angles (as in the case of TwinJet nozzles) may produce better coverage if the canopy is not dense. But, in dense canopy conditions, flat-fan nozzles with single spray pattern producing medium quality spray tend to provide a better penetration of droplets inside canopy.
3. Air-assisted sprayer did a better job with penetration of droplets into canopy and spray coverage than a conventional sprayer.
4. Mechanically opening the canopy with a well-designed mechanical canopy opener, conventional boom sprayers may provide coverage and penetration nearly as good as those from air-assisted sprayers. However, the canopy opener will not be effective in reducing drift which is one more benefit achieved from air-assisted sprayers.
5. At 15 gal/acre and 7 mph, and under dense canopy conditions, flat fan nozzles provided better coverage and penetration into the canopy than the hollow cone nozzle.

## Acknowledgements

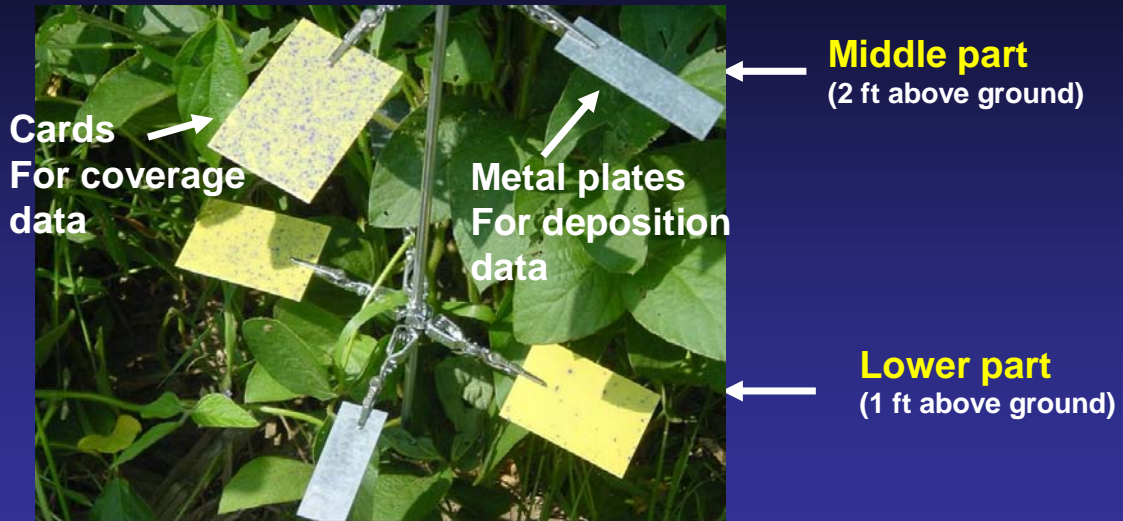
The help provided by by Keith Diedrick, OSUE Extension Educator at Wayne County, Ohio, during spraying of plots and collection of samples from the plots was much appreciated.

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# Targets placed in the canopy (56', 75' and 95' into each plot)



**Spray Solution:** Water + Fluorescent tracer  
(Brilliant Sulfaflavne 7.5 gr/gal)

## NOZZLE types used in the study

XR Flat Fan



Turbo TeeJet



Turbo TeeJet DUO



TX Hollow Cone



TwinJet