13

Evaluation of Soybean (*Glycine max*) Canopy Penetration with Several Nozzle Types and Pressures

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1. Introduction

Fungicides, when applied in the most effective way, can greatly improve the efficacy of the fungicide, reduce the risk of resistance, and potentially increase yields or preserve crops. When making fungicide applications, there are several things that must be considered. Most sprayers use hydraulic nozzles with pressure against an orifice. The applicator must consider which type of nozzle to use (both orifice size and nozzle type) as well as operating pressure.

Soybean rust is a foliar disease which has for many years been found mainly in Asian countries such as Taiwan, Japan, India, and more recently South Africa, Paraguay, Brazil, and Argentina (Dorrance, et al, 2009). *Phakopsora pachyrhizi* is one of the fungal species known to cause soybean rust and is the most aggressive. This species was identified in US soybean production fields in November of 2004. US cultivars are thought to be highly susceptible to this fungus, and efforts are underway to identify partial resistance or slow rusting traits. Fungicides have proven to be very effective in managing this disease and this will be the primary means of management for the first several years.

Soybean rust in the early days following infection can be found on the lower, first leaves of soybean plants (Geiseler, 2009). Therefore, to obtain control with fungicides one must penetrate the soybean canopy and get the fungicide down to where the infection occurs.

The objective of this study is to determine the optimum spray particle size that delivers the greatest coverage at lower levels of the soybean canopy.

Since the key to this research is the spray nozzle tip let's discuss spray nozzle tip technology.

The spray nozzle tip is important because it:

1. Controls the amount applied - GPA
2. Determines the uniformity of application
3. Affects the coverage
4. Affects the spray drift potential
5. Breaks the mix into droplets
6. Forms the spray pattern
7. Propels the droplets in the proper direction

Where does one start in choosing a spray nozzle tip? The two important factors are pesticide efficacy and spray drift management.

Applicators want to use low water volumes to save time which makes coverage more of a concern. One needs knowledge of the product being used, whether it is a systemic or contact pesticide. Contact pesticides, such as paraquat, need more thorough coverage than systemic pesticides like glyphosate. Most fungicides and insecticides require thorough coverage which requires a smaller spray droplet size. Will this smaller droplet size penetrate the canopy? Also, what is the target? Is it soil, or grass, or broadleaf plants. Are the plant surfaces smooth, or hairy, or waxy? Leaf orientation and even the time of day of the application can affect the coverage needed and hence pesticide efficacy.

2. 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, low pressure, drift guard, venturi-type and turbos are available for some nozzle types.

2.1 Flat-fan

Flat-fan nozzles, used for broadcast spraying, produce a tapered-edge spray pattern. These nozzles are also available for band spray. These nozzles are called even flat-fans, which produce a pattern with the same amount applied across the entire spray pattern. Other flat-fan nozzle subtypes include the standard flat-fan, even flat-fan, low pressure flat-fan, extended range flat-fan, drift guards, Turbo TeeJet, and some special types such as off-center flat-fan and twin-orifice flat-fan.

The **standard** flat-fan normally is operated between 2.07 and 4.14 bar, with an ideal range 2.07 and 2.76 bar. The **even** (E) flat-fan nozzles (nozzle number ends with E) 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, spray angle, and the orientation of the nozzles.

The **low pressure** (LP) flat-fan develops a normal flat-fan angle and spray pattern at operating pressures between 1.03 and 1.72 bar. Lower pressures result in larger droplets and less drift, but a LP nozzle produces smaller droplets than a standard nozzle at the same pressure.

The **extended range** (XR or LFR) flat-fan provides excellent drift control when operated between 1.03 and 1.72 bar. This nozzle is ideal for an applicator who likes the uniform distribution of a flat-fan nozzle and desires lower operating pressure for drift control. Since extended range nozzles have an excellent spray distribution over a wide range of pressures 1.03 to 4.14 bar, they are ideal for sprayers equipped with flow controllers if spray particle drift is not a problem.

The **Turbo TeeJet** has the widest pressure range of the flat-fan nozzles - 1.03 to 6.21 bar. It produces larger droplets for less drift and is available only in 110 degree spray angle.

The **drift guard** flat-fan has a pre-orifice which controls the flow. The spray tip is approximately one nozzle size larger than the pre-orifice and therefore produces larger droplets and reduces the small drift prone droplets.

The **venturi-type** nozzle produces large air-filled drops through the use of a venturi air aspirator for reducing drift. These include the Delavan Raindrop Ultra, Greenleaf TurboDrop, Lurmark Ultra Lo-Drift, Spraying Systems AI Teejet, ABJ Agri. Products Air Bubble Jet, and Wilger's Combo-Jet. Some of these nozzle tips are available in extended range for pressures.

Flat-fan nozzles also include the **off-center** (LX) flat-fan which is used for boom end nozzles so a wide swath projection is obtained and the **twin-orifice** (TJ) flat-fan which produces two spray patterns -- one angled 30 degrees forward and the other directed 30 degrees backwards. The TJ droplets are small because the spray volume is passing through two smaller orifices instead of one larger one. 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 2.07 and 4.14 bar.

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 1.

	Spray height (cm)			
	51 cm Spacing With Overlap of		76 cm Spacing With Overlap of	
Nozzle angle^o	30%	100%	30%	100%
65	56	-NR-	-NR-	-NR-
73	51	-NR-	73.7	-NR-
80	43	66	66	97
110	25	38	36	64

-NR- Not recommended because of drift potential.

Table 1. Suggested minimum spray heights.

The correct nozzle height is measured from the nozzles to the target, which may be the top of the ground, growing canopy, or stubble. Use 110 degree nozzles when boom heights are less than 76 cm and 80 degree nozzles when the booms are higher.

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

Most nozzle manufacturers identify their 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 discharge 1.9 liters per minute (LPM) at the rated pressure of 2.75 bar. A 11002 nozzle has a 110 degree spray angle and will discharge 0.8 LPM at the rated pressure of 2.75 bar. Additional designations are: " BR" - brass material; "SS" - stainless steel; "VH" - hardened stainless steel; and "VS" - color codes. See Table 2 for nozzle type and discharge rates.

Nozzle Type	Discharge (lpm)	Rated Pressure (bar)	Operating Range	
			Min (bar)	Max (bar)
Regular flat-fan 8006	2.3	2.76	2.07	4.14
Regular flat-fan 11008	3.0	2.76	2.07	4.14
Low pressure flat-fan 8006LP	2.3	1.03	1.03	2.76
Low pressure flat-fan 11008LP	3.0	1.03	1.03	2.76
Extended range flat-fan 8006XR	2.3	2.76	1.03	4.14
Extended range flat-fan 11008XR	3.0	2.76	1.03	4.14
Turbo TeeJet TT11002VP	0.8	2.76	1.03	6.21
Turbo TeeJet TT11005VP	1.9	2.76	1.03	6.21
Turbo TeeJet Induction TTI11002	0.8	1.03	2.76	6.89
Turbo TeeJet Induction TTI11005	1.9	1.03	2.76	6.89
Drift Guard DG8002VS	0.8	2.76	2.76	4.14
Drift Guard DG11005VS	1.9	2.76	2.07	4.14
AI TeeJet AI11002-VS	0.8	2.76	2.07	6.89
AI TeeJet AI11005-VS	1.9	2.76	2.07	6.89
AIXR TeeJet 11002VS	0.8	2.76	1.03	6.21
AIXR TeeJet 11005VS	1.9	2.76	1.03	6.21
Flood TKSS 6	2.3	0.69	0.69	2.76
Flood TKSS 8	3.0	0.69	0.69	2.76
Turbo FloodJet TF-VS2	0.8	0.69	0.69	2.76
Turbo FloodJet TF-VS10	3.8	0.69	0.69	2.76
Raindrop RA-6	2.3	2.76	1.38	3.45

Table 2. Nozzles types and discharge rates at rated pressure.

Delavan 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 1.9 LPM at the rated pressure of 2.75 bar.

2.2 Flood

Flood nozzles are popular for applying suspension fertilizers where clogging is a potential problem. These nozzles produce large droplets at pressures of 0.69 to 1.72 bar. The nozzles should be spaced less than 152 cm apart. The nozzle height and orientation should be set for 100 percent overlap.

Nozzle spacing between 76 and 102 cm produces the best spray patterns. Pressure influences spray patterns of flood 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.

Flooding nozzles are designated “TK” by Spraying Systems and “D” by Delavan. The value following the letters is the flow rate at the rated pressure of 0.69 bar. For example, TK-SS2 or D-2 are flood nozzles that apply 0.8 LPM at 0.7 bar.

The Turbo FloodJet incorporates a pre-orifice which controls the flow plus a turbulence chamber. The tip design more closely resembles a flat fan nozzle, which greatly reduces the surface area and the result is a much improved pattern with tapered edges. Use the turbo flood for pesticide application for incorporated herbicides because of the improved pattern. The turbo flood nozzles are a good choice if drift is a concern because they produce larger droplets than standard flood nozzles. Because of their large droplet size do not use the turbo flood nozzle where good coverage is needed.

2.3 Raindrop

Raindrop nozzles produce large drops in a hollow-cone pattern at pressures from 1.38 to 3.45 bar. The "RA" Raindrop nozzles are used for pre-plant incorporated herbicide and are usually mounted on tillage implements. When used for broadcast application, nozzles should be orientated 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 small number of large droplets produced would not provide satisfactory coverage.

2.4 Cone

Hollow-cone - Hollow cone nozzles 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 2.76 to 6.89 bar. Spray drift potential is higher from hollow-cone nozzles than from other nozzles due to the small droplets produced.

Full-cone - Full-cone nozzles usually are recommended over flood nozzles for soil-incorporated herbicides. Full-cone nozzles operate between a pressure range of 1.03 to 2.76 bar. Optimum uniformity is achieved by angling the nozzles 30 degrees and overlapping the spray coverage by 100 percent.

Fine Hollow-cone - The ConeJet (Spray Systems) and WRW-Whirl Rain (Delavan) are wide-angle (80 to 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 under a hood for band spraying. Drift potential is great for these nozzles.

2.5 Nozzle material

Nozzles can be made from several materials. The most common are brass, nylon, stainless steel and hardened stainless steel and ceramic. 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. Ceramic has superior wear life and is highly resistant to abrasive and erosive chemicals. Where available ceramic is usually the best choice.

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.

2.6 Combination nozzles

These are where the spray tip is built right into the cap as one. These keep the spray tip and cap from separating and when available is usually the best choice.

2.7 When to replace nozzles

- Spray pattern distorted
- Nozzles show irregular wear
- Nozzle flow rates is 10% greater than new nozzles

Note: Each nozzle's flow rate on spray boom needs to be within 5% of the average nozzle flow rate.

Spray particle size affects both pesticide efficacy (coverage) and spray drift. Cutting the droplet size in half results in eight times the number of spray droplets, see Figure 1.

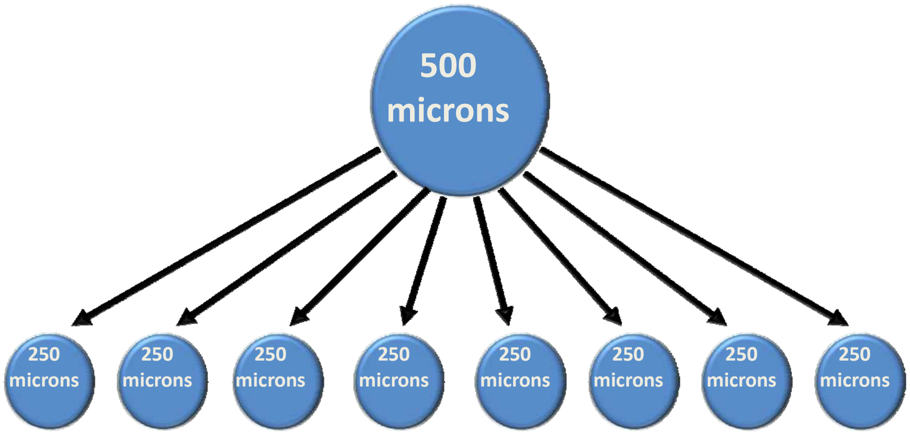


Fig. 1. Reducing droplet size by 50% results in eight times the number of droplets

The origin of standardization of spray droplet sizes started with the British Crop Protection Council in 1985 with droplet size classification, primarily designed to enhance efficacy. It uses the term, *SPRAY QUALITY* for droplet size categories. In 2000 the ASAE Standard S572 established the droplet size classification in the U.S. primarily designed to control spray drift and secondarily efficacy. It uses the term *DROPLET SPECTRA CLASSIFICATION* for droplet size categories. In March 2009 ANSI/ASAE approved S572.1 as the American National Standard. This added extremely fine and ultra coarse to the classification categories.

The specifics of the Standard ASAE S572.1.

- Based on spraying water through reference nozzles
- Nozzle manufacturers can conduct the tests
- Must use a set of reference tips and a laser-based instrument
- Droplet Spectra measurements must be with the same instrument, measuring method, sampling technique, scanning technique, operator, and in a similar environmental condition.

Important Droplet Characteristics:

Dv0.1(µm) - 10% of spray volume is of droplet sizes less than this number
Dv0.5(µm) - 50% of spray volume is of droplet sizes less than this number; volume median diameter (VMD)
Dv0.9(µm) - 90% of spray volume is of droplet sizes less than this number

Though not part of the standard, the percent of spray volume less than 200 microns identifies the particle sizes most prone to spray drift.

Figures 2 and 3, and Table 3 illustrate volume median diameter, the ASAE Standard and a Turbo TeeJet spray tip droplet spectra.

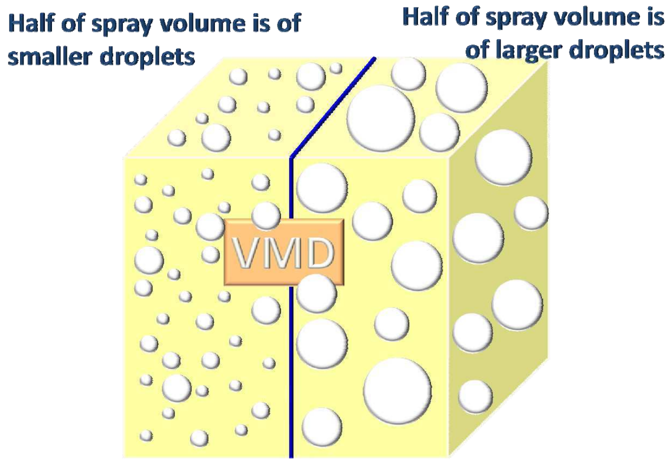


Fig. 2. Volume Median Diameter (VMD)

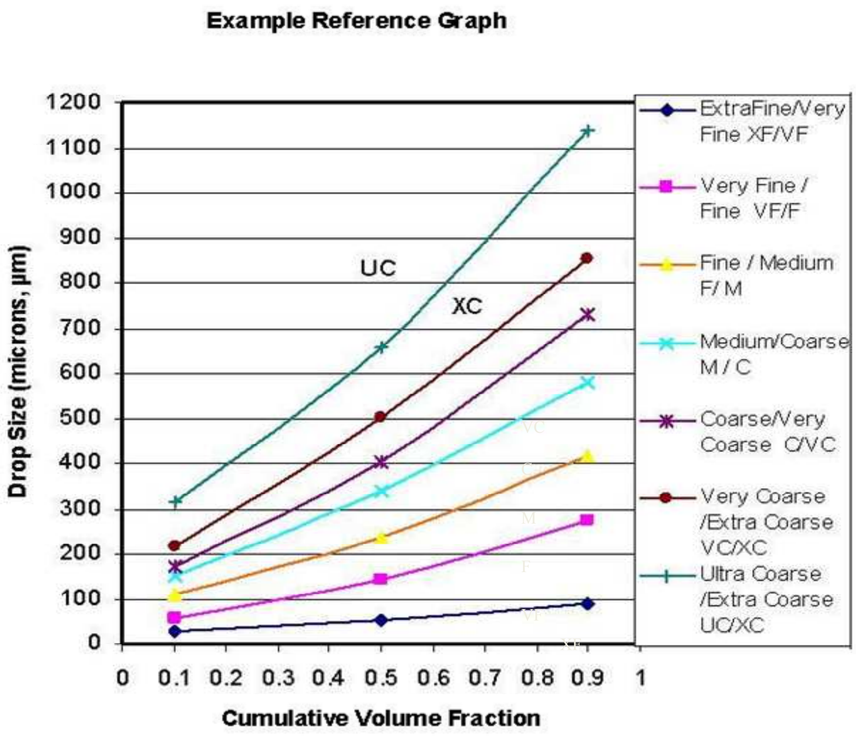


Fig. 3. ANSI/ASAE S572.1 March 2009; Approved as an American National Standard

Nozzle 	Bar										
	1.03	1.38	1.72	2.07	2.41	2.76	3.45	4.14	4.83	5.52	6.21
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 3. Turbo TeeJet® Nozzle Droplet Spectra

Three nozzle tips were evaluated for the control of triazine resistant kochia and green foxtail in winter wheat stubble. The treatment parameters used to evaluate the nozzle tips and percent control are shown in Table 4 and Figures 4 and 5.

Trt	**Nozzle**	**Spray Particle Size**	**Volume**		**Speed**	
			(gpa)	(L/ha)	(mph)	(km/h)
1	XR11005	Coarse	10	94	8.6	14
2	DG11005	Coarse	10	94	8.6	14
3	TF-VS2.5	Extremely Coarse	10	94	8.6	14
4	XR11004	Medium	7.5	70	9.2	15
5	DG11004	Coarse	7.5	70	9.2	15
6	TF-VS2	Extremely Coarse	7.5	70	9.2	15
7	XR11003	Fine	5.0	47	10.3	17
8	DG11003	Coarse	5.0	47	10.3	17
9	Untreated Check			---		---

*All treatments applied at 2 bar
*Herbicide applied was Paraquat + Atrazine (0.35 + 0.56 Kg ai/ha)

Table 4. Treatment parameters used to evaluate three nozzle types

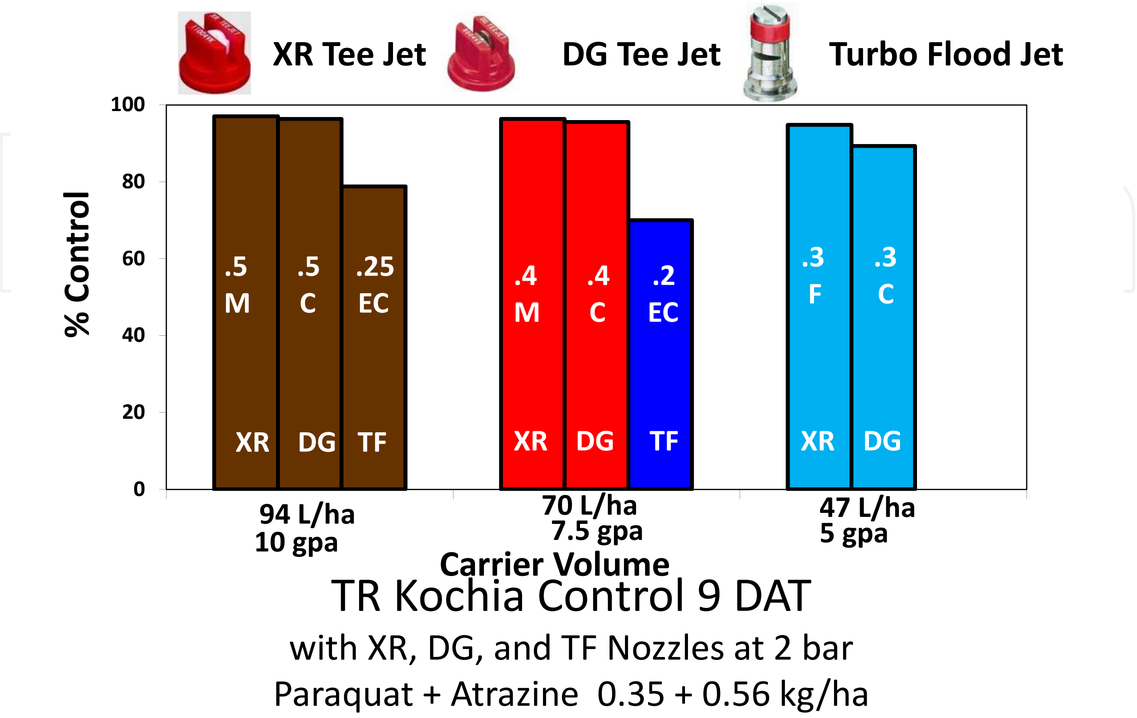


Fig. 4. Triazine resistant kochia control with several nozzles and carrier volumes

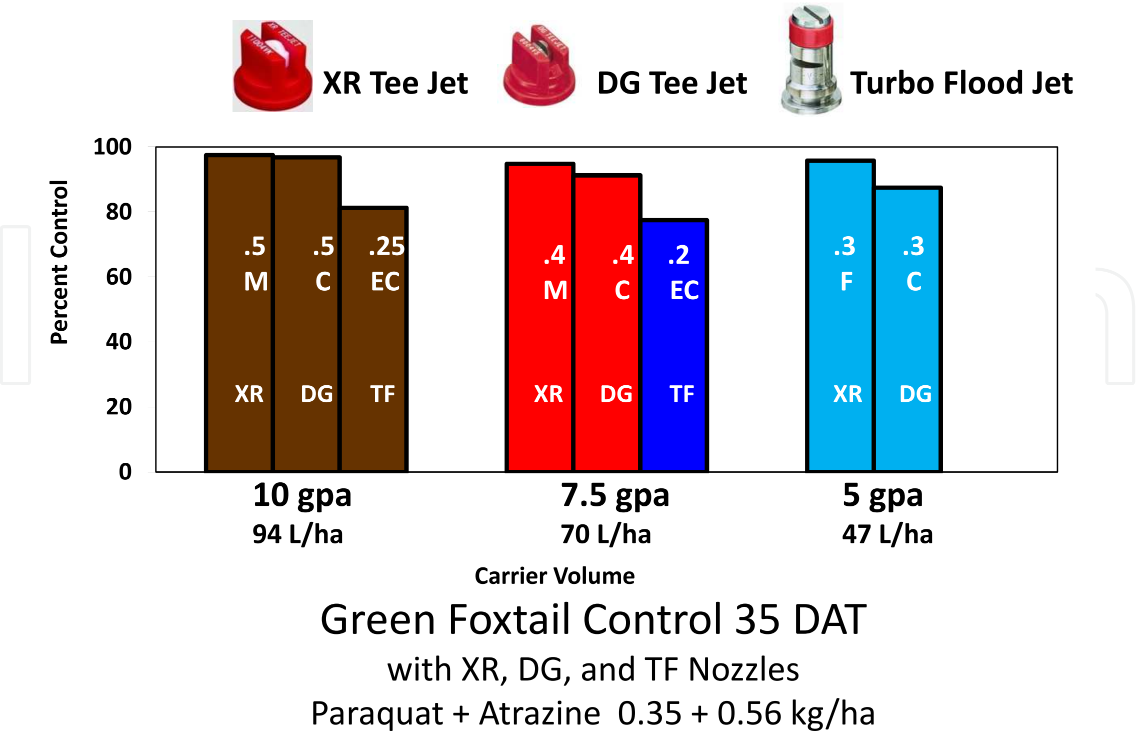
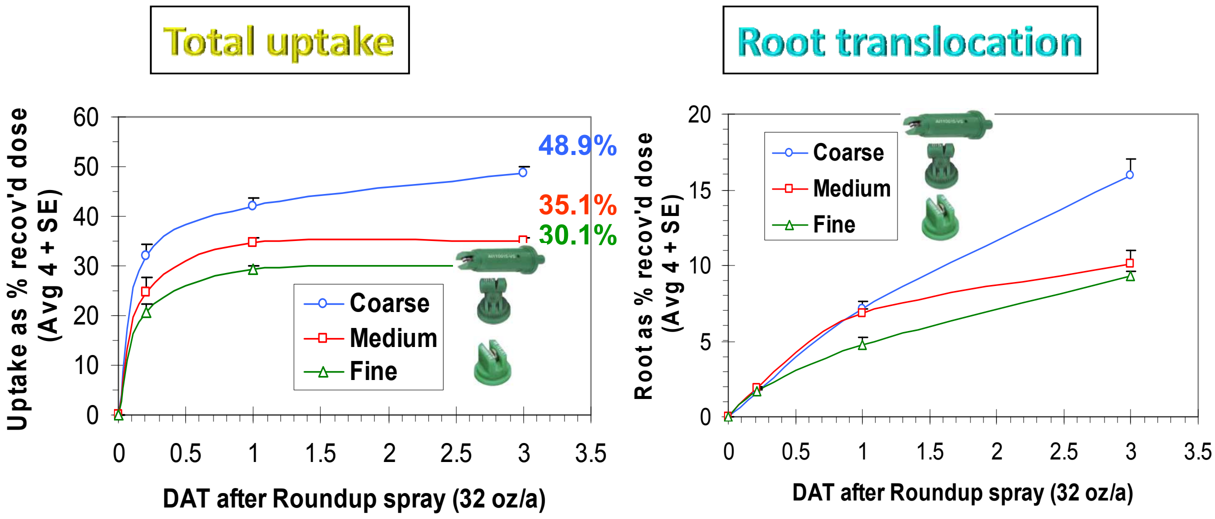


Fig. 5. Green foxtail control with several nozzles and carrier volumes

The results of a study on the retention and total uptake and root translocation of glyphosate of glyphosate resistant corn by Paul Feng of Monsanto are in Table 5 and Figure 6.

Droplet Size	% Retention (Actual over Calculated)
Fine	47 ± 2
Medium	37 ± 7
Coarse	38 ± 8

Table 5. Effect of droplet size on glyphosate retention in glyphosate resistant corn



Feng et al., Weed Sci, in press.

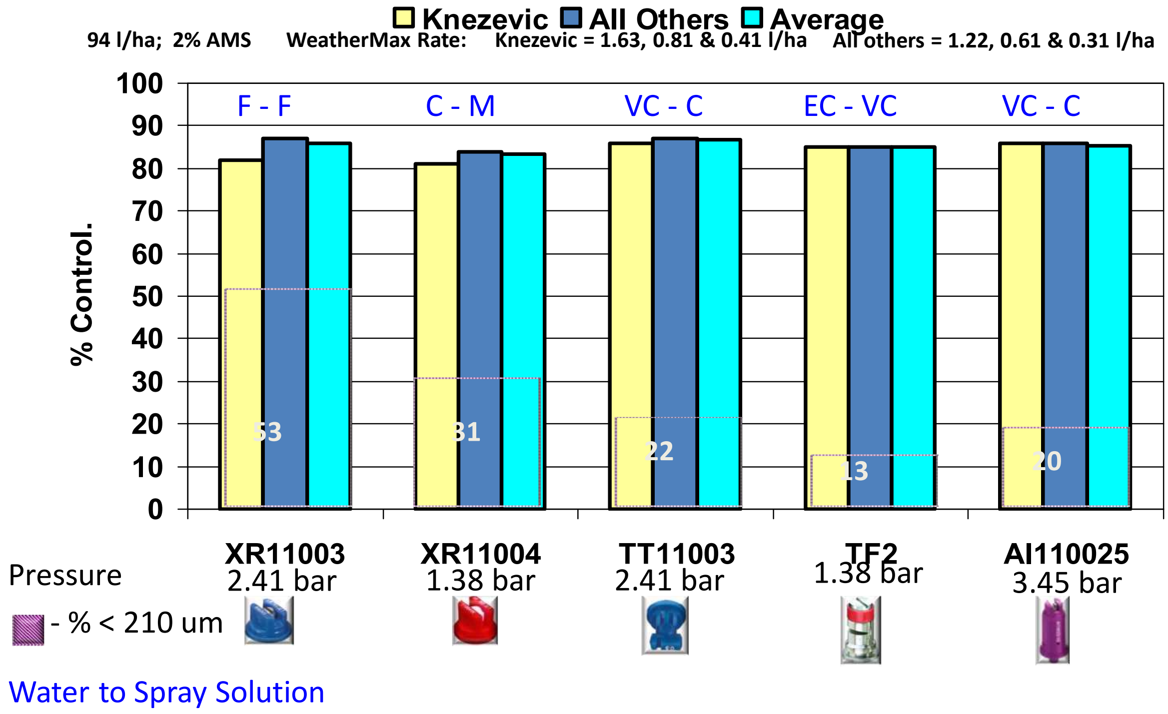
Paul Feng, Monsanto

Fig. 6. Uptake and translocation in glyphosate resistant corn with fine, medium and coarse spray droplets.

In the glyphosate resistant corn study even though there was less glyphosate retained on the plants with the coarse droplet size as compared to the fine, the coarse droplet size resulted in increased uptake and root translocation. It is thought that there must be enough glyphosate present in the spray droplet to translocate in the plant.

A study across Nebraska in 2004 with five nozzle tips resulted in almost identical weed control. One should therefore select those tips which produce the smallest amount of fines which are the Turbo TeeJet, Turbo Flood and Air Induction nozzle tips. See Figure 7.

Figure 8 gives the particle sizes of five nozzle tips with water and water with Roundup WeatherMax + 2% Ammonium Sulfate and three additives: Array, In-Place and Interlock.



R. Klein, S. Knezevic, A. Martin, R. Wilson, B. Kappler and F. Roeth, 2004

Fig. 7. Percent visual control of corn, oil sunflower, velvetleaf, green foxtail and watermemp with glyphosate.

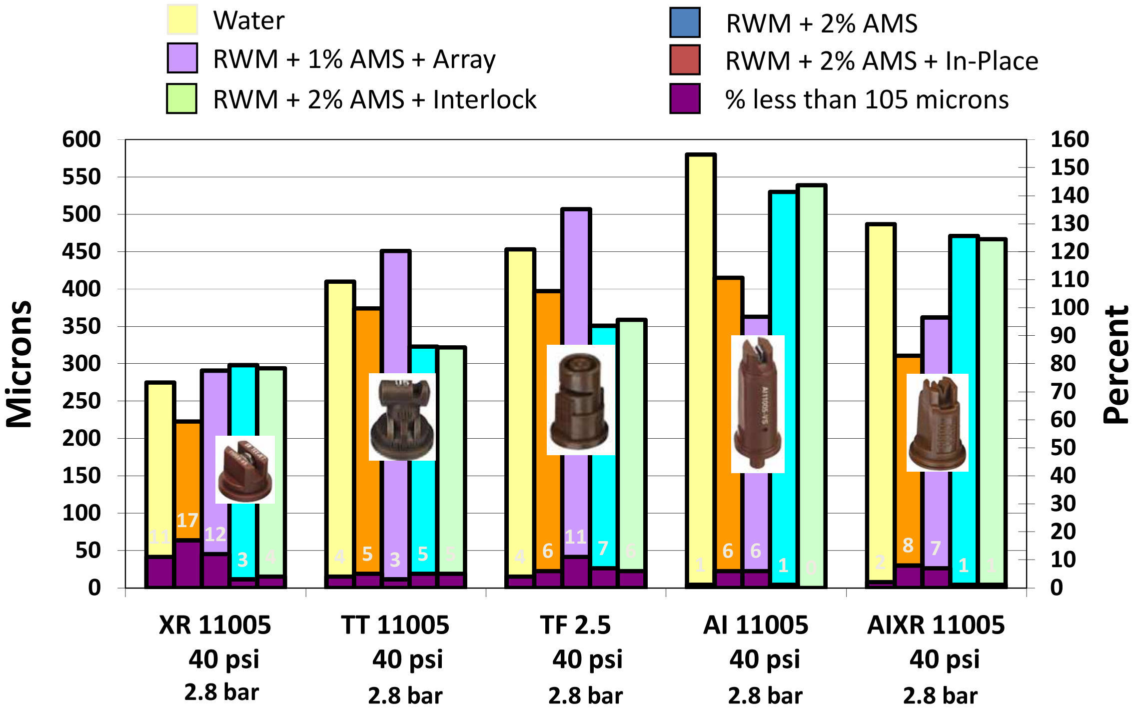


Fig. 8. Volume median diameter of several nozzles and spray solutions.

The volume median diameter of the spray particle sizes are greatly reduced as was the amount of spray volume under 210 microns with the addition of Roundup WeatherMax and 2% AMS. The additive Array increased the volume median diameter and reduced the amount of spray volume under 210 microns with the extended range, Turbo TeeJet and Turbo Flood nozzles. The additives In-Place and Interlock performed with similar results with the air induction and extended range air induction tip. All additives do not work with all nozzles as evident in Figure 9.

To evaluate the nozzle tips, pressure, nozzle spacing and angle in getting penetration into the soybean canopy, research was conducted over several years. Soybeans were planted in 76.2 cm rows in May 2006, 2007, and 2008. Field applications were conducted in August and September of these years. Six different nozzles were included, all Spraying Systems Co: XRC11003, XRC11006, TT11003, TT11006, AIC110025, and AIC11005. Each nozzle was used at three pressures, and two different nozzle setups were included. Nozzles were set on 76.2 cm spacing, and 190 l ha^{-1} was the carrier volume (Table 6). For the smaller nozzle size of each type, two nozzles were used: one directed 45 degrees forward from vertical and the other directed 45 degrees back from vertical. Boom height was 43.2 cm above the canopy. White indicating cards were set into a row of soybeans. The cards were attached to an electric fencepost at heights of 14 cm (low), 42 cm (middle) and 70 cm (high), with the soybeans being 84 cm tall. A pull type sprayer was used to apply the treatments. Water dyed with Garrco Products Vision Pink indicating dye was sprayed over the cards. Four sets of cards were placed for each treatment to create four replications. A nozzle setup ran directly over the row of soybeans containing the cards. The cards were allowed to dry and placed in Ziploc bags. The cards were then scanned with the program DropletScan, which determines the number of drops, volume median diameter (VMD) and percent coverage for each card. VMD is the micron size of which half the spray volume in made of smaller droplets and half is of larger droplets.

Treatment	Nozzle(s)	Pressure bar	Total Nozzle Output L min^{-1}	Speed km hr^{-1}
1	XRC 11003 (2)	1.03	1.36	05.8
2		2.07	1.97	08.2
3		4.14	2.80	11.8
4	XRC 11006	1.03	1.36	05.8
5		2.07	1.97	08.2
6		4.14	2.80	11.8
7	TT 11003 (2)	1.03	1.36	05.8
8		2.07	1.97	08.2
9		4.14	2.80	11.8
10	TT 11006	1.03	1.36	05.8
11		2.07	1.97	08.2
12		4.14	2.80	11.8
13	AIC 110025 (2)	2.07	1.67	05.8
14		4.14	2.35	08.2
15		6.21	3.88	11.8
16	AIC 11005	2.07	1.67	05.8
17		4.14	2.35	08.2
18		6.21	3.88	11.8

Table 6. Nozzles and pressures used in soybean canopy penetration study.

The nozzles were also analyzed with a Sympatec Helos Vario KF particle size analyzer. With the R6 lens installed, it is capable of detecting particle sizes in a range from 0.5 to 1550 microns. This system uses laser diffraction to determine particle size distribution. Each treatment was replicated three times. The width of the nozzle plume was analyzed by moving the nozzle across the laser by means of a linear actuator. Information obtained includes VMD.

3. Results

The results of coverage on the cards scanned with the program DropletScan are reported in Table 7. This includes the three pressures, VMD and the percent coverage on the lower, middle and upper cards. Also listed in the table are the laser VMD for each nozzle and pressure. Results are from 2006, 2007 and 2008 combined.

		Lower Card		Middle Card		Upper Card		Laser
Nozzle(s)	Pressure	VMD[a]	Pct Cov[b]	VMD[a]	Pct Cov[b]	VMD[a]	Pct Cov[b]	VMD[a]
	Bar	µm	%	µm	%	µm	%	µm
XRC11003 (2)	1.03	267	0.92	293	4.11	342	13.14	382
	2.07	231	0.86	239	4.06	316	10.45	244
	4.14	230	0.56	237	3.50	285	8.81	189
XRC11006	1.03	395	1.01	374	3.44	453	7.85	465
	2.07	314	0.70	338	4.18	394	12.56	316
	4.14	309	0.68	330	4.47	390	10.95	262
TT11003 (2)	1.03	352	1.46	408	4.37	506	16.27	516
	2.07	314	1.09	394	4.16	448	13.63	380
	4.14	268	1.05	344	2.50	394	12.67	254
TT11006	1.03	392	1.21	454	3.98	572	11.10	640
	2.07	379	0.81	417	5.20	504	11.46	406
	4.14	326	1.43	334	3.25	400	11.14	347
AIC110025 (2)	2.07	438	0.82	519	3.70	582	10.18	677
	4.14	376	0.37	376	2.79	480	8.73	532
	2.28	333	0.64	351	2.21	429	9.09	462
AIC11005	2.07	454	0.94	448	3.95	550	10.94	662
	4.14	403	0.85	433	3.80	485	10.43	508
	2.28	349	1.23	407	4.77	461	11.22	436
	LSD 5%	70	0.58	52	2.14	38	3.48	29

[a] Volume median diameter
[b] Percent coverage

Table 7. Volume median diameter (VMD) and percent coverage for various nozzles, pressures and card placement in soybean canopy.

4. Discussion

The figures 9, 10 and 11 contain results of VMD and percent coverage of the card in the three card levels in soybean canopy for the 3 years, 2006 to 2008. Data in the figures represents the average of the three pressures used, while Table 7 includes data for each pressure. With the lower card, the TT11003 had the best coverage closely followed by the TT11006. With the XRC nozzles, as the pressure increased the coverage decreases in the lower canopy. This was also true with the smaller TT (2-TT11003 in opposite directions) but the larger TT spraying straight down and the AIC nozzle coverage decreased with the medium pressure but increased again with the highest pressure. The two TT11003 had the highest amount of coverage of the three nozzle types in the study.

For the lower card, laser VMD was larger than card VMD for each nozzle. As particle size increased (comparing nozzle types), the difference between the VMD's increased, especially at laser VMD sizes of 375 µm and greater. For the middle card, the two VMD's were equal up to 375 µm. Above this point, laser VMD once again becomes larger. For the upper card, card VMD was greater than laser VMD up to laser VMD being 450 µm. Above that, card VMD was smaller. This suggests larger particles landed in the upper canopy, especially for nozzles producing a smaller VMD (smaller particle size). The nozzles producing the highest percent coverage of the lower card were the TT11003 and TT11006. These nozzles produced a laser VMD of 383 µm and 464 µm respectively, suggesting a micron size of around 400 may be optimal.

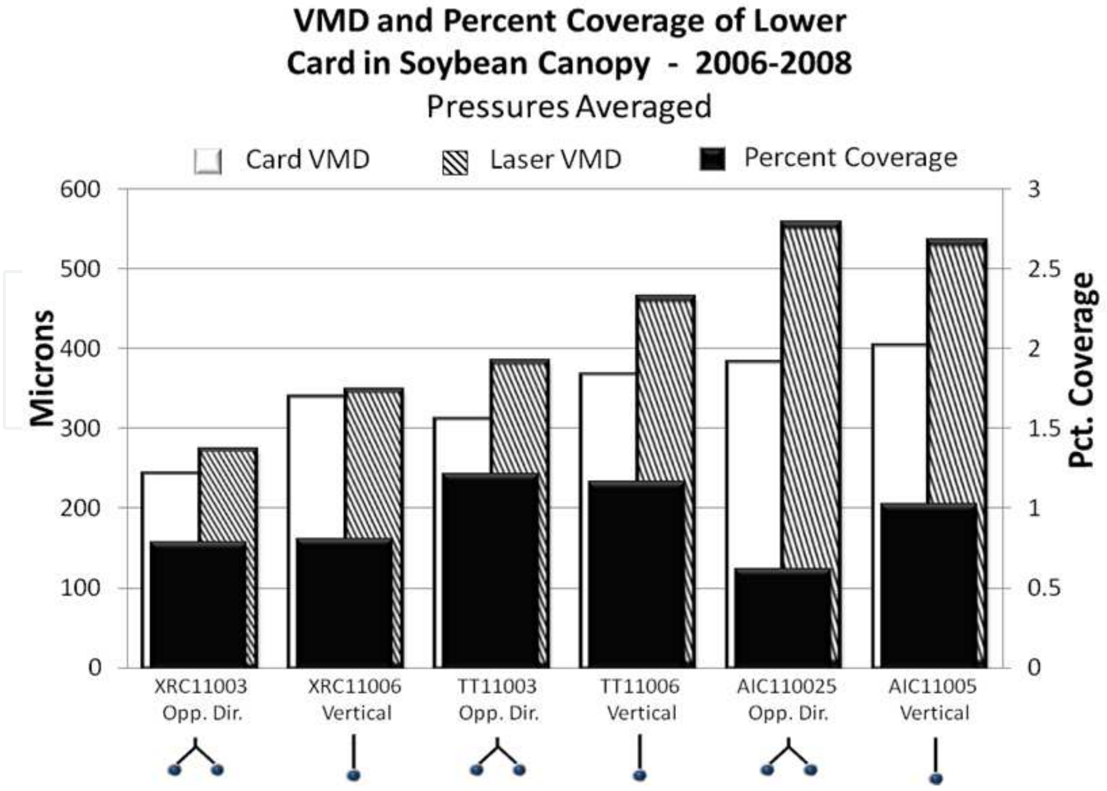


Fig. 9. VMD and percent coverage of lower card in soybean canopy

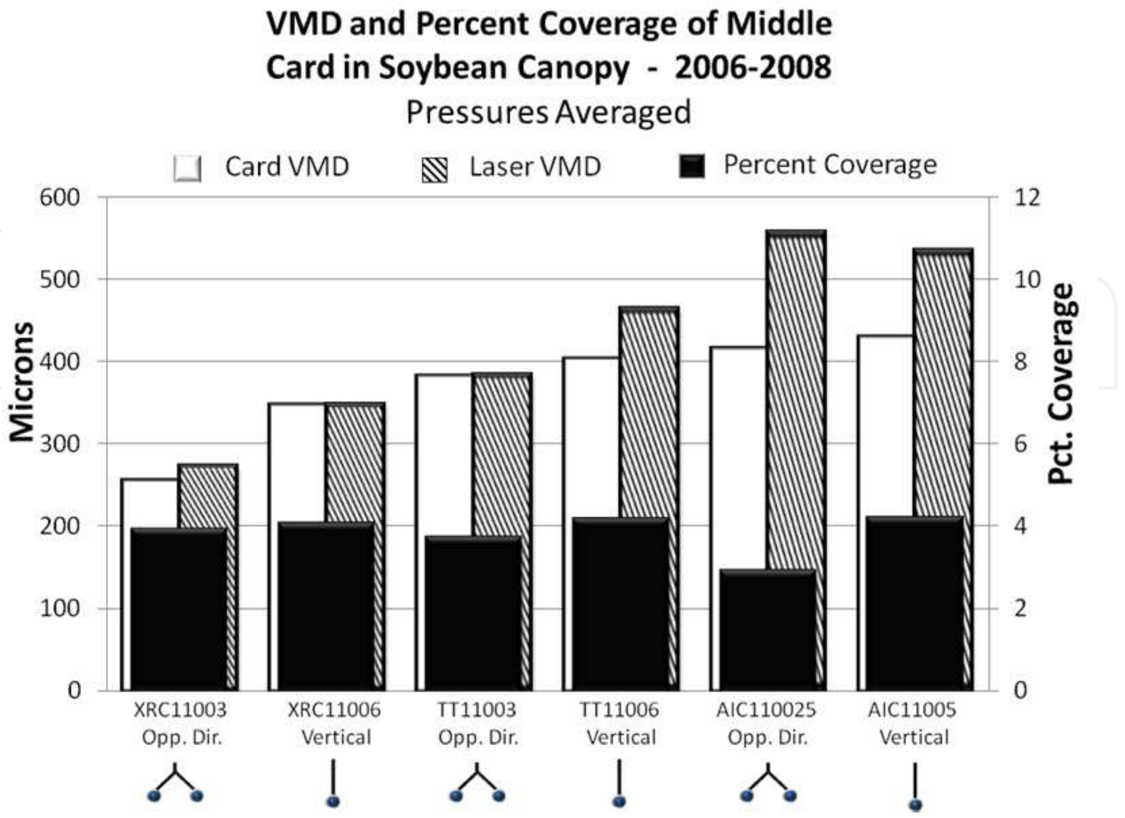


Fig. 10. VMD and percent coverage of middle card in soybean canopy

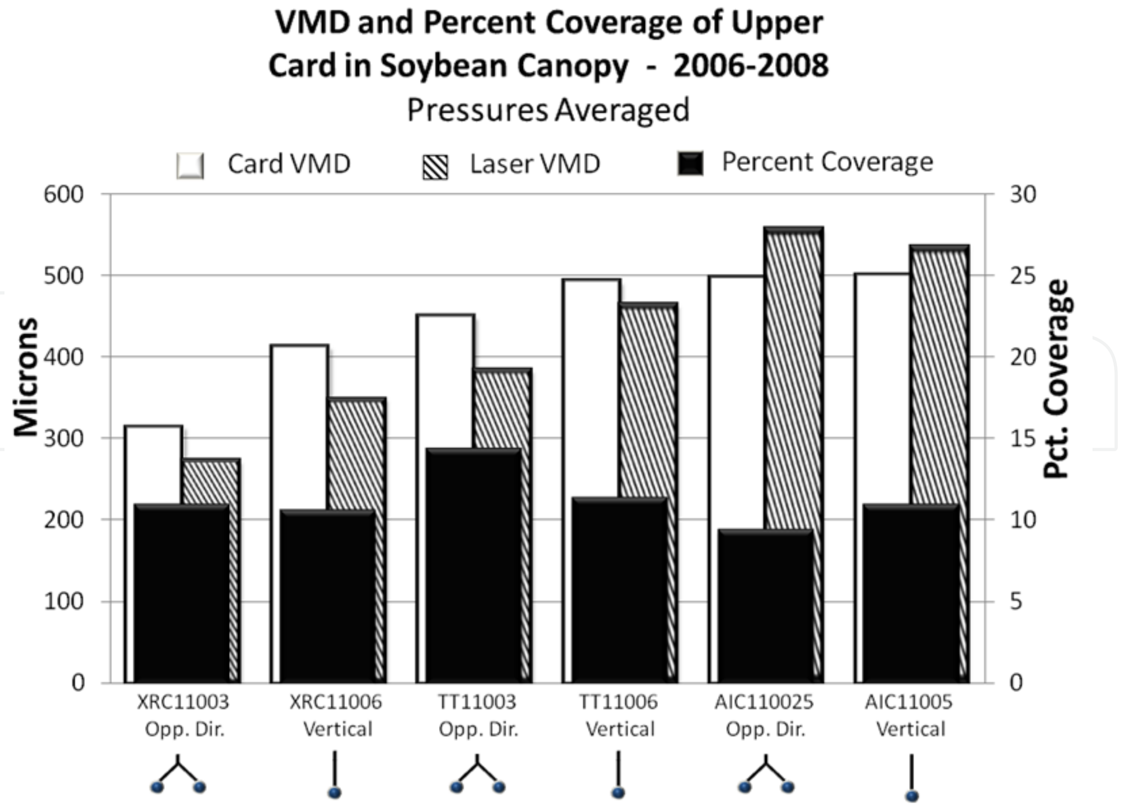


Fig. 11. VMD and percent coverage of upper card in soybean canopy

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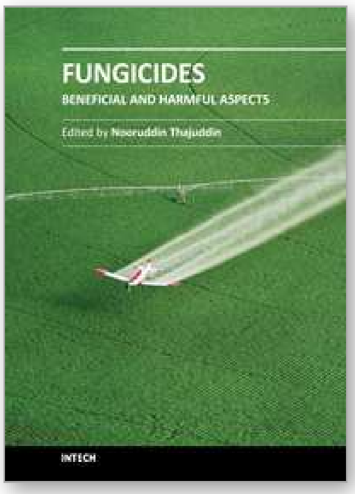

Fungicides - Beneficial and Harmful Aspects
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Fungicides are a class of pesticides used for killing or inhibiting the growth of fungus. They are extensively used in pharmaceutical industry, agriculture, in protection of seed during storage and in preventing the growth of fungi that produce toxins. Hence, fungicides production is constantly increasing as a result of their great importance to agriculture. Some fungicides affect humans and beneficial microorganisms including insects, birds and fish thus public concern about their effects is increasing day by day. In order to enrich the knowledge on beneficial and adverse effects of fungicides this book encompasses various aspects of the fungicides including fungicide resistance, mode of action, management fungal pathogens and defense mechanisms, ill effects of fungicides interfering the endocrine system, combined application of various fungicides and the need of GRAS (generally recognized as safe) fungicides. This volume will be useful source of information on fungicides for post graduate students, researchers, agriculturists, environmentalists and decision makers.

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