2018-2019 MN Soybean Research and Promotion Council

Title: *Understanding spatial and temporal changes in Minnesota soybean pests (Year III)*

Bruce Potter, Dr. Dean Malvick and Dr. Angie Peltier

Progress Quarter 4. February 1, 2019 – April 30, 2019 and (Final)

Objective I. *Develop a framework for long-term monitoring of soybean pests and pathogens.* *(Team: Bruce Potter, Dean Malvick, Angie Peltier)*

Progress

- Sentinel plots containing varieties believed susceptible to several pathogens and to SCN were planted at University of Minnesota Research and Outreach Centers located at Lamberton, Waseca, Rosemount, Morris and Crookston. To accommodate local production practices the plot size, row spacing, and varieties at the Crookston site are dissimilar from the southern sites, necessitating separate analyses.
- Early, mid and late season soybean stand, disease and insect assessments were made at all locations.
- We made visual late-season disease ratings from the sentinel plots containing varieties believed susceptible to one of several pathogens or to SCN. SCN females were observed on roots of the susceptible variety at Morris. Frogeye leaf spot was unusually prevalent but only at the Morris and Lamberton sites. Additional pest information can be found in the 2019 MN Ag Expo display presentation in Appendix A.
- Funding supplied by this project helped Extension personnel to make field visits to NW Minnesota producer fieldsto diagnose unknown disease issues. Diagnoses and management recommendations were shared with each producer.
- On November 30, Potter, Malvick, several other University of Minnesota faculty and the Minnesota Soybean Research Director participated in a meeting on the St. Paul campus of the University of Minnesota. The purpose of the meeting was to discuss the development of a MN system to store historical information on pest populations and combine predictive models. This project has the potential to help facilitate development.
- Varieties for the 2019 Sentinel and fungicide study were confirmed. Due to the availability of seed, numerous adjustments were needed.

Challenges

- Obtaining soybean varieties that have known disease susceptibilities remains difficult and might well be dropped in future efforts. It would be beneficial if public breeding programs could develop soybean isolines to use in testing programs and to standardize resistance scores across companies. MNSR&PC may be able to play a role in encouraging these developments.
- Wet conditions delayed planting at the Lamberton and Waseca locations.

- Water damaged some of the sentinel varieties at the Lamberton location. These plots were not intended to be taken to yield and were still be rated for disease..
- Maintaining focused efforts on a comprehensive pest survey system for Minnesota is challenging.
- Based on the results at a single SWROC location, it would be useful to re-institute the standardized insecticide protocol at other locations to help monitor insecticide resistance in soybean aphid populations and their associated yield impacts.

Objective II a. ***Develop a framework for testing pesticide efficacy in an ongoing, systematic way.*** *(Team: Bruce Potter, Dean Malvick, and Angie Peltier with additional University and Industry collaboration).*

Progress

- Results from the previous year's fungicide testing were the focus of a 2018 MN Crop News article/ http://blog-crop-news.extension.umn.edu/2018/06/evaluating-responses-of-soybean-to.html.
- Fungicide trial studies were planted at the same time as the sentinel studies listed in Objective I. Headline and Delaro fungicides were applied to three varieties at University of Minnesota Research and Outreach Centers at Lamberton, Waseca, Rosemount, Morris and Crookston between July 17 and July 31. Insects and diseases were rated at the time of fungicide applications and again at the end of season.
- Fungicide applications produced a yield benefit at the three southern locations but not at the Crookston and Morris sites.
- At the Morris location, neither fungicide treatment affected frogeye leafspot severity or yield
- Additional pest information on yield, moisture responses and potential economic benefits can be found in the 2019 MN Ag Expo display presentation (Appendix A)

Challenges

- Equipment to apply multiple fungicide treatments to a plot containing tall soybeans is an issue. A limited number of treatments can be applied with a CO2 backpack sprayer. Although outside the scope of this project, if obtaining good fungicide data is a priority, infrastructure support for high-clearance pesticide application equipment is important.
- Wet weather delayed planting at the Waseca site. The Crookston site received hail, greatly reducing yield.
- Portions of two fungicide study replications at the Lamberton location were damaged by ponded water. Fungicide applications were moved to another area and variety. Unfortunately, because of the difference in soybean varieties, the fungicide data from Lamberton could not be combined with the other two southern sites. In addition to the wet growing season in the southern portion of Minnesota, the wet fall delayed plot harvest and data analyses.

- In spite of these challenges, some reasonably interesting results were obtained.

Objective II b. ***Since weed management can greatly influence pest populations (e.g. soybean cyst nematode, soybean aphid, and corn rootworm), a weed research and demonstration component at a SW MN location will include volunteer corn and volunteer soybean control***.

Progress

- Experimental methods, results and conclusions for the SW location of the multi-site soybean herbicide performance study are presented in Appendix B.

- Experimental methods, results and conclusions for a study examining the potential impact of herbicide tolerant soybean on soybean aphid and soybean cyst nematode and herbicide performance study are presented in Appendix C.

Challenges

- While soybean aphids were observed in the volunteer soybean study at the beginning of the season, these populations did not persist through the spring's high moisture conditions. Late-season infestations of the volunteer soybean study by aphids occurred only at the edges of plots.

- Similar to conditions faced by farmers, 2018 weather was difficult and interfered with timing of planting and data collection. The volunteer soybean study was completed but the herbicide performance on volunteer corn study was not.

- The soybean weed management study was planted very late due to wet soil conditions and chronic rainfall. This planting date influenced the weed density and species complex. Pre-emerge and glyphosate and glufosinate post-emerge herbicide treatments were applied. Calendar restrictions meant that post emerge dicamba treatments were not applied.

Tech Transfer 2018-19

Tech transfer highlights during 2018-19 include:

- An article describing previous year's results with this study was posted in a June 19, University of Minnesota Crop News article **https://blog-crop-news.extension.umn.edu/2018/06/evaluating-responses-of-soybean-to.html**. A 2019 article on this study is in prep.

- The 2019 MN Ag Expo display presentation (https://swroc.cfans.umn.edu/sites/swroc.cfans.umn.edu/files/2019_soybean_ag_expo_for_web.pdf , has been available for download on the internet since late January.

- Potter, Malvick and Peltier discussed this study and more generally, factors to consider when making foliar fungicide decisions in MN during field days at Crookston and Rosemount. Fall and early winter meetings discussions included the UMN Crop Pest Management Shortcourse, University of Minnesota Ag Professional Research Updates, Research and Outreach Center Research Center Research Updates, the ten-location

MSRPC-sponsored Strategic Farming programs and several County Soybean Grower Association annual meetings. Radio programs in northwest and southern Minnesota provided another outreach outlet. *During the 2018-19 project period, more than 1350 meeting attendees were exposed to these MN MN Research and Promotion Council funded studies and initial results.*

Reviewed Publications

Peltier, A.J., Potter, B.D. and Malvick, D.M. 2019. Effects of foliar fungicides and varieties on yield and leaf and stem diseases of soybean in Crookston, Minnesota in 2018. Plant Dis. Mgmt. Rep. 13:CF061.

MN Multi-Site Foliar Fungicide Trials and Pest Sentinels

Variety and Fungicide Effects on Soybean Yield

Bruce Potter, Dean Malvick, Angie Peltier & Travis Vollmer

University of Minnesota Extension

Funding provided by Minnesota Soybean Research and Promotion Council

By evaluating results of a network of standardized fungicide trials over time, Minnesota soybean farmers and their advisors will have information to better understand:

- Return on pesticide investments.
- Yield impacts from plant disease.
- Evidence that disease prevalence or soybean susceptibility has changed.

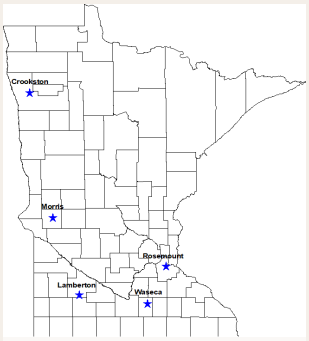


Figure 1. Locations of foliar fungicide trials 2016-18. (Morris added 2017, Crookston 2018).

During the 2016-18 growing seasons, a strobilurin fungicide and mixes of a strobilurin with a triazole or SDHI fungicide (Table 1) were applied to multiple soybean varieties (Table 2) at several UMN Research and Outreach Centers (Figure 1). Fungicides were applied at labeled rates and 15 GPA to soybeans at the R3 stage. At these same locations, sentinel varieties, presumed to be susceptible to one or more target pathogens, were planted to help detect disease. In addition to soybean yield, information on several key insects and diseases were recorded (Table 6).

Table 1. FUNGICIDES EVALUATED

TRADE NAME	FUNGICIDE and GROUP*	YEARS
Headline® BASF	pyraclostrobin (11)	2016-18
Stratego® YLD BAYER	prothioconazole (3) + trifloxystrobin (11)	2016
Delaro™ BAYER	prothioconazole (3) + trifloxystrobin (11)	2017-18
Priaxor® BASF	fluxapyroxad(7) + pyraclostrobin 11)	2016

** (11) strobilurin 3) triazole (7) SDHI*

Table 2. YEAR and SOYBEAN VARIETIES INCLUDED

SITE	2016	2017	2018
Lamberton			AG 14X8
Waseca	AG 1832 AG 2035 P 22T69	S 20-T6 S 20-T6* AG 2035	NK S20-T6 P 20T79R AG 21X7
Rosemount			NK S20-T6 P 20T79R AG 21X7
Morris		P 1091 AG 1435 CH 1216 R2X	AG1435 AG 11X8 P21A59
Crookston			CH 0518 R2X P 03T68 R2

* With Cruiser Maxx Insecticide/Fungicide seed treatment

Table 3. Factorial Analysis of Variance 2016

YIELD @13% moisture and 60 lb./bu.

Source	Prob > F COMBINED	LAMBERTON	WASECA§	ROSEMOUNT
Site	0.9903 [a]			
Variety	**0.0005** ****	**0.0022** ****	**0.0032** ****	**0.0254** ***
Fungicide	**0.0028** ****	**0.0070** ****	0.1771 *	**0.0077** ****
Variety * Fungicide	0.6379	0.5709	0.4677	0.4371
Site * Variety	0.1646 *			
Site * Fungicide	0.8890			
Site * Variety * Fungicide	0.8924			

% MOISTURE

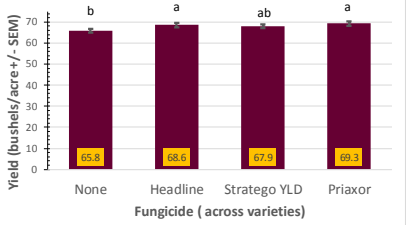
Source	Prob > F COMBINED	LAMBERTON	WASECA§	ROSEMOUNT
Site	0.7906			
Variety	**0.0001** ****	**0.0001** ****	**0.0020** ****	**0.0052** ****
Fungicide	**0.2759**	0.2647	0.4115	0.3595
Variety * Fungicide	0.8758	0.5709	0.8387	0.4344
Site * Variety	**< 0.0001** ****			
Site * Fungicide	0.7501			
Site * Variety * Fungicide	0.7949			

[a]Combined site Analysis of Variance (ANOVA) based on normalized yields and moistures (plot site/mean)

Significant at alpha: ** 0.20, ** 0.10, ***0.05 ,****0.01*

§Waseca site with 3 replications due to wet field conditions, Lamberton and Rosemount with 4

Figure 2. 2016 Fungicide Response - Across Sites



2016: Soybean varieties differed in yield at individual sites and across sites ($P \leq 0.05$). Varieties differed in moisture, dissimilarly among sites. A lack of site and variety interactions allowed the pooling of fungicide yields across sites and varieties (Table 3).

Fungicides yielded 2.1-3.5 bushels greater yield than untreated soybeans (Figure 2). Soybean varieties responded similarly to fungicide application at the study three sites. Moisture was not affected.

Figure 3. Pod and stem blight
(Signs of fungus on a senesced stem and disease symptoms on maturing pods)

Rated disease pressure was generally low. Pod and stem blight (Figure 3) was easily found in eastern sites. Soybean aphids reached economic threshold only at Lamberton.

2017: Soybean yields differed by variety and differed by location (Table 4). At the three southern locations, two varieties were tested, one of these treated with a Cruiser Maxx insecticide/fungicide seed treatment and one without. Seed treatment had no effect on yield at any of the three southern locations.

For more information contact: bpotter@umn.edu

MN Multi-Site Foliar Fungicide Trials and Pest Sentinels

Variety and Fungicide Effects on Soybean Yield

Bruce Potter, Dean Malvick, Angie Peltier & Travis Vollmer

University of Minnesota Extension

Table 4. Factorial Analysis of Variance 2017

YIELD @13% moisture and 60 lb./bu.

Source	Prob > F				
	COMBINED§	LAMBERTON§§	WASECA	ROSEMOUNT	MORRIS
Site	0.9940 [a]				
Variety	**<0.0001** ****	**0.0228** ***	0.1345 *	**< 0.0001** ****	**0.0080** ****
Fungicide	0.1113 *	0.1726 *	0.8121	**0.0012** ****	0.0670 **
Variety * Fungicide	0.7275	0.8156	0.8058	0.3262	0.4043
Site * Variety	**<0.0001** ****				
Site * Fungicide	0.1246 *				
Site * Variety * Fungicide	0.9044				

% MOISTURE

Source	Prob > F				
	COMBINED§	LAMBERTON§§	WASECA	ROSEMOUNT	MORRIS
Site	0.9966				
Variety	**0.0254** ***	0.8911	**0.0181** ***	0.8515	0.0684 **
Fungicide	0.4225	0.1957 *	0.3485	**0.0059** ****	0.7798
Variety * Fungicide	0.5936	0.5624	0.5186	0.9394	0.5433
Site * Variety	**0.0023** ****				
Site * Fungicide	0.2218				
Site * Variety * Fungicide	0.6006				

[a]Combined site Analysis of Variance (ANOVA) based on normalized yields and moistures (plot/site mean)

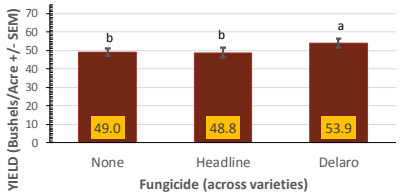
§ Due to unique varieties - Morris not included in combined sites

Significant at alpha: * 0.20, ** 0.10, ***0.05 ,****0.01

Unlike 2016, although fungicide impacted yield and moisture ($P \leq 0.05$), the difference was only observed at the Rosemount site. Only Delaro showed a higher yield than untreated (Figure 4).

Brown stem rot (Figure 5) was prevalent on some varieties at Lamberton and Rosemount. Late planting may have minimized this disease at Waseca and Morris. Fungicide had no impact on this disease although it reduced *Septoria* brown spot (Figure 6) in some cases.

Figure 4. 2017 Fungicide Response - Rosemount



Although white mold (Figure 7) was a problem in many 2017 soybean fields, it was present at low levels in these study sites.

Soybean aphids reached economic threshold levels at Morris and Lamberton only. Non–economic populations of Japanese beetle (Figure 8) and bean leaf beetle were observed only at Rosemount..

Figure 5. Brown stem rot
Early foliar symptoms

Figure 6. Brown spot
(Septoria)

Figure 7. White mold

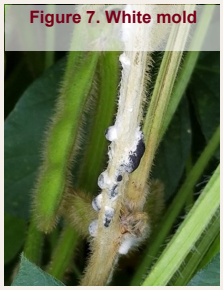


Figure 8. Japanese beetle

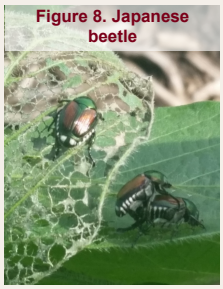


Table 5. Factorial Analysis of Variance 2018

YIELD @13% moisture and 60 lb./bu.

Source	Prob > F					
	COMBINED§	LAMBERTON§§	WASECA	ROSEMOUNT	MORRIS	CROOKSTON§§
Site	0.9279 [a]					
Variety	0.0822 **		0.1822 *	0.2195	0.2065	0.5308
Fungicide	**<0.0000** ****	**0.0092** ****	**0.0150** ***	**0.0008** ****	0.1938 *	0.3395
Variety * Fungicide	0.1546 *		0.0619 **	0.6430	0.2695	0.8176
Site * Variety	0.1363 *					
Site * Fungicide	0.7296					
Site * Variety * Fungicide	0.1363 *					

% MOISTURE

Source	Prob > F					
	COMBINED§	LAMBERTON§§	WASECA	ROSEMOUNT	MORRIS	CROOKSTON§§
Site	0.9985					
Variety	0.6307		**0.0156** ***	0.2149	0.1405 *	**< 0.0001** ****
Fungicide	**0.0189** ***	0.2857	0.6323	**0.0222** ***	0.7351	0.4650
Variety * Fungicide	0.5645		0.8803	0.5980	0.3172	0.3609
Site * Variety	0.5330					
Site * Fungicide	0.1595 *					
Site * Variety * Fungicide	0.5330					

[a]Combined site Analysis of Variance (ANOVA) based on normalized yields and moistures (plot/site mean)

§ Due to unique varieties - Lamberton, Morris, and Crookston not included in combined sites

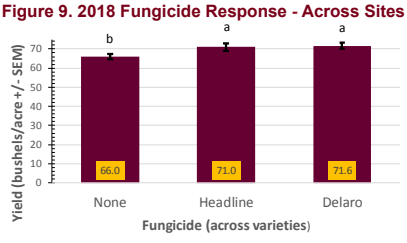
§§ Flooding damaged original study at Lamberton and fungides applied to a single variety. Crookstoon site was hailed.

Significant at alpha: * 0.20, ** 0.10, ***0.05 ,****0.01

2018: Soybean varieties yielded similarly within sites except Crookston. Fungicide impacted yield and moisture across all the three southern sites but not at Morris and Crookston (Table 5).

Across Rosemount and Waseca and the single Lamberton variety, both Headline and Delaro yielded more than the same varieties without fungicide (Figure 9).

Figure 9. 2018 Fungicide Response - Across Sites



Frogeye leafspot (Figure 10) was unusually prevalent at the Morris and Lamberton sites with varietal differences noted at Morris. Historically, this disease has been present but not common in MN and should be watched for and increase in prevalence. Wet weather increased the severity of bacterial blight and *Septoria* brown spot in several sites. Other diseases were present but at relatively low in prevalence.

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Bean leaf beetle were observed at both Rosemount and Morris signaling these insects may be starting to rebound. Soybean aphids (Figure 11) reached economic threshold earliest at Morris, then Lamberton, and then later at Waseca and Rosemount. Crookston populations remained below threshold. This was similar to commercial fields in these areas.

While not observed at these sites, a new species, the soybean gall midge (Figure 12) has been found in MN. Through the North Central Soybean Research Program, checkoff dollars will support 2019 work on this insect in Minnesota.

Figure 10. Frogeye leaf spot

Figure 11. Soybean aphid

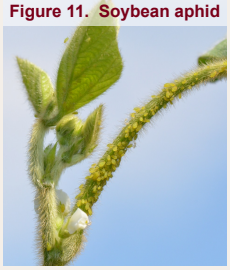


Figure 12. Soybean gall midge
Rock County, MN 2018

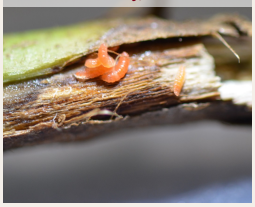


Table 6. Pest levels at study sites	Lamberton			Waseca			Rosemount			Morris		Crookston
Pest Insects	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**	**2016**	**2017**	**2018**	**2017**	**2018**	**2018**
Soybean Aphid	> 250/plant	> 250/plant	> 250/plant	<50/plant	< 50/Plant	> 250/plant	<50/plant	< 50/plant	> 250/plant	> 250/plant	> 250/plant	< 50/Plant
Japanese Beetle	-	-	-	-	-	-	< 5% defol.	< 10% defol.	< 10% defol.	-	-	-
Bean Leaf Beetle	-	-	-	-	-	-	-	< 1% defol.	< 1% defol.	-	< 1% defol.	-
Disease	**% plants infected**											
Brown Stem Rot (stem symptoms)	7.5	95	0	6.6	0	0	15	96	10	<1	0	0
White mold	2.5	0	0	0	+	0	2.5	+	0	<1	0	0
Pod and stem blight	0	2.5	0	27	0	0	12.5	0	0	0	0	80
Stem canker	0	0	0	0	0	0	25	+	0	0	0	0
Phytopthora	0	3	0	0	2.5	0	0	0	0	3	0	0
Rhizoctonia (stem lesions)	10	2.5	0	10	0	0	2.5	+	0	0	0	0
Sudden Death Syndrome	0	0	0	0	0	0	5	0	0	0	0	0
Brown spot (mid-upper canopy)	<10	100	100	<10	25	100	+	+	100	40	100	0
Bacterial blight (mid-upper canopy)	50	100	100	<10	100	100	+	+	40	25	0	0
Cercospora Blight	0	0	0	0	0	100	0	0	0	0	0	60
Frogeye Leaf Spot	0	0	100	0	0	100	0	0	0	0	100	0

Disease scores are based on late season samples and represent the most severely affected sentinel variety or fungicides study plot for each year, at each location.
Insect ratings reflect abundance and economic status. The yellow cells highlight interesting temporal and spatial pest differences.

		Yield benefit [1] (Bu/A)			Soybean value ($/Bushel) $8.00			$10.00			$12.00		
Location	**Year**	**ST [2]**	**ST+TR [3]**	**S+SDHI [4]**	**ST [2]**	**ST+TR [3]**	**S+SDHI [4]**	**ST [2]**	**ST+TR [3]**	**S+SDHI [4]**	**ST [2]**	**ST+TR [3]**	**S+SDHI [4]**
Lamberton	***2016***	*1.7*	***2.5***	***3.5***	NSYB	NSYB	**$28.00**	NSYB	NSYB	**$35.00**	NSYB	NSYB	**$42.00**
Waseca	***2016***	*2.2*	*1.4*	*3.1*	NSYB	NSYB	NSYB	NSYB	NSYB	NSYB	NSYB	NSYB	NSYB
Rosemount	***2016***	***4.8***	***2.7***	***4.3***	**$38.40**	NSYB	**$34.40**	**$48.00**	NSYB	**$43.00**	**$57.60**	NSYB	**$51.60**
Average	***2016***	***2.8***	***2.1***	***3.5***	**$22.40**	**$16.80**	**$28.00**	**$28.00**	**$21.00**	**$35.00**	**$33.60**	**$25.20**	**$42.00**
Lamberton	***2017***	*1.4*	*4.7*		NSYB	NSYB		NSYB	NSYB		NSYB	NSYB	
Waseca	***2017***	*-0.9*	*-1.5*		NSYB	NSYB		NSYB	NSYB		NSYB	NSYB	
Rosemount	***2017***	*-0.2*	***4.9***		NSYB	**$39.20**		NSYB	**$49.00**		NSYB	**$58.80**	
Average*	***2017***	*-0.4*	***2.2***		NSYB	NSYB		NSYB	NSYB		NSYB	NSYB	
Lamberton	***2018***	***5.5***	***5.4***		**$13.50**	**$43.20**		**$55.00**	**$54.00**		**$66.00**	**$64.80**	
Waseca	***2018***	***5.4***	***3.9***		**$13.40**	**$31.20**		**$54.00**	**$39.00**		**$64.80**	**$46.80**	
Rosemount	***2018***	***6.2***	***6.0***		**$14.20**	**$48.00**		**$62.00**	**$60.00**		**$74.40**	**$72.00**	
Average*	***2018***	***5.1***	***5.4***		**$13.10**	**$43.20**		**$51.00**	**$54.00**		**$61.20**	**$64.80**	

[1] The yields in the gray shaded cells were not statistically different from untreated (NSYB no significant yield benefit)
[2] Headline [3] 2016 Stratego YLD, 2017-18 Delaro [4] Priaxor
* Morris, Crookston and 2018 Lamberton not included due to the use of different varieties.

Table 7. Yield and economic benefit for fungicide application in Southern MN. Fungicide costs run from $7.25 to $17.00 ***plus*** application.

Fungicides provided a positive yield response in 7 of 9 site-years at the three southern sites (Table 7). Responses varied by site and year. Fungicide did not significantly affect yield or moisture at Morris or Crookston. *Overall, 7 of 12 site-years showed higher yield with fungicide*.

Moisture differences may be influencing yield response and these might change with harvest timing.

Over the three southern sites, Headline showed a 3.6% yield advantage while Stratego YLD and Delaro showed a 4.6% yield advantage. Grain was 1.6 and 2.8% wetter, respectively.

Potential returns for individual products and studies were calculated for several hypothetical several soybean prices (Table 7). These can be compared against product and application costs.

- Fungicides can maintain yield in some environments and provide an economic benefit if used selectively but profitable responses to fungicide are not consistent.
- Moisture and harvestability may be influencing fungicide yield responses.
- Disease and insect pressure varies by year and location.
- Applications of foliar fungicides on an insurance basis cannot overcome poor variety selection and other agronomic decisions.

Appendix B

Herbicide performance in soybeans at Lamberton, MN in 2018.

Travis D. Vollmer, Bruce D. Potter, Jeffrey L. Gunsolus, and Thomas R. Hoverstad.

The objective of this study was to evaluate soybean pre-emerge and post-emerge herbicide combinations for the Xtend and Liberty Link soybean systems. This study was conducted on a Normania loam soil containing 4.0% organic matter, pH 5.6 and soil test P and K levels of 19 and 113 ppm, respectively. A randomized complete block design with four replications and a plot size of 10 by 30 ft was used. The site was planted to corn in 2017 and a mulch ripper was used for fall tillage. On June 4, 2018, two varieties of soybeans were planted; Asgrow '20X7' glyphosate and dicamba tolerant soybeans and Croplan 'LC1864' glyphosate and glufosinate tolerant soybeans were planted in 30-inch rows at a seeding rate of 160,000 seeds/A. All treatments were applied with a tractor-mounted sprayer delivering 15 gpa at a pressure of 35 psi. The sprayer was equipped with 8002 flat-fan nozzles (pre) and 11002 TT nozzles (post) spaced 15 inches apart on the boom. Application dates, environmental conditions, plant sizes and rainfall data are listed in Table 1 below:

Date	June 5	June 6	July 10
Treatment	PRE	PRE (dicamba)	POST I
Temperature (F)			
air	85	75	71
soil (4 inch)	78	78	81
Relative humidity (%)	48	49	71
Wind (mph)	ESE 7	E 9	S 5
Sky	Clear	Cloudy	Cloudy
Soil moisture	Dry	Dry	Dry
Soybean			
crop stage.	-	-	V5
height (inch)	-	-	10

Date	June 5	June 6	July 10
Yellow Foxtail / Barnyard Grass			
leaf no.	-	-	1 to 3
height (inch)	-	-	2 to 7
no./ft^2	-	-	< 1
C. lambsquarters			
leaf no.	-	-	2 to 3
height (inch)	-	-	3 to 4
no./ft^2	-	-	1
Waterhemp			
leaf no.	-	-	1 to 5
height (inch)	-	-	3 to 5
no./ft^2	-	-	7
1 week rainfall	1.83	2.01	1.15
2 week rainfall	1.47	2.22	1.84
3 week rainfall	3.30	2.84	0.05

(Southwest Research and Outreach Center, University of Minnesota, Lamberton).

This site has been managed for a large tall waterhemp seedbank. Other broadleaf and grass weed species were present but emerged at moderate or low population densities. To avoid crop injury, soybeans were blocked by variety and the glufosinate (Liberty 280) and dicamba (Engenia) applications intended only for respective tolerant varieties. Similar to problems experienced by area growers, the late planting date, weather, and field conditions combined to prevent planned post-emerge dicamba treatments before the June 20 cutoff date requirement in the Minnesota label.

Because the study include two unrelated soybean varieties, the comparison of yields among herbicide treatments was based on both raw and adjusted yields. For each of the herbicide

tolerant varieties, yields were adjusted by dividing the treatment by the respective untreated check yield.

Temporary, early-season injury was observed with all Group 14 and 15 PRE herbicides and with the Flexstar GT POST treatments.

Pre-emerge treatments performed similarly in both herbicide tolerant systems. All provided excellent control of tall waterhemp and common lambsquarters. Numerically, Authority First, Surveil, and Zidua Pro PRE treatments provided slightly less grass control. By the end of season, all treatments containing a PRE herbicide displayed similar weed control. The glyphosate (Roundup PowerMax) POST without a PRE had fewer grassy weeds than untreated checks but more than other herbicide treatments and it performed similarly on tall waterhemp. The glufosinate (Liberty 280) POST without a PRE provided less tall waterhemp control than other treatments, similar to untreated check.

With the exception of the Authority First PRE treatment, all herbicide treatments applied to the Liberty Link variety yielded similarly and were highest yielding among all treatments. Among the treatments applied to the Xtend variety, the Prefix PRE followed by Roundup Powermax resulted in the highest yield, equivalent to the high yielding Liberty Link treatments.

The untreated Liberty and Xtend checks, Zidua Pro PRE followed by Flexstar plus Select POST, Engenia Pro PRE followed by Flexstar GT POST, Prefix PRE followed by Flextar GT POST, Fierce MTZ followed by Flexstar GT POST, and Authority Supreme followed by Flexstar GT were lowest yielding. This may have been due to crop injury.

Weed control and yield results are given in Table 2.

Table 2. Pre-emerge herbicide Performance in Soybeans at Lamberton, MN in 2018 (Vollmer, Potter, Gunsolus and Hoverstad).

Treatment	Rate	Injury	Yellow Foxtail / Barnyard Grass			Lambsquarters			Waterhemp			Yield	Adjusted Yield
		Jul 23	Jul 9	Jul 23	Oct 16	Jul 9	Jul 23	Oct 16	Jul 9	Jul 23	Oct 16		
		(1 < 5)	(% control)									(bu/A)	
Preemergence/Post I (4" Weeds)													
Authority First / Flexstar GT + MSO + AMS	6.4 oz / 3.5 pt + 1 % + 1.5 qt	1	92 a	99 a	99 a	97 a	99 a	99 a	97 ab	99 a	99 a	61.1 b-g	1.104 b-f
Surveil / Flexstar GT + MSO + AMS	3 oz / 3.5 pt + 1 % + 1.5 qt	1	60 a	99 a	99 a	99 a	99 a	99 a	95 ab	99 a	99 a	58.8 fgh	1.064 e-h
Prefix / Roundup Powermax + AMS	2 pt / 32 oz + 1.5 qt	0	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	62.8 abc	1.135 a-d
Fierce MTZ / Flexstar GT + MSO + AMS	16 oz / 3.5 pt + 1 % + 1.5 qt	1	97 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	53.7 j	0.972 i
Zidua Pro / Flexstar GT + MSO + AMS	5 oz / 3.5 pt + 1 % + 1.5 qt	1	97 a	99 a	99 a	99 a	99 a	99 a	98 ab	99 a	99 a	55.4 ij	1.001 hi
Authority Supreme / Flexstar GT + MSO + AMS	8 oz / 3.5 pt + 1 % + 1.5 qt	1	97 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	56.7 hij	1.024 ghi
Warrant Ultra / Flexstar GT + MSO + AMS	3 pt / 3.5 pt + 1 % + 1.5 qt	0	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	59.6 d-h	1.077 c-g
Authority First / Liberty 280 + AMS	6.4 oz / 32 oz + 1.5 qt	1	71 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	60.5 c-g	1.105 b-f
Surveil / Liberty 280 + AMS	3 oz / 32 oz + 1.5 qt	0	97 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	63.7 ab	1.169 ab
Prefix / Liberty 280 + AMS	2 pt / 32 oz + 1.5 qt	0	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	63 abc	1.156 ab
Fierce MTZ / Liberty 280 + AMS	16 oz / 32 oz + 1.5 qt	0	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	62.5 a-d	1.143 abc
Zidua Pro / Liberty 280 + AMS	5 oz / 32 oz + 1.5 qt	0	73 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	97 a	63.8 ab	1.168 ab
Authority Supreme / Liberty 280 + AMS	8 oz / 32 oz + 1.5 qt	0	99 a	99 a	99 a	99 a	99 a	99 a	99 a	98 a	96 a	62.4 a-e	1.145 abc
Warrant Ultra / Liberty 280 + AMS	3 pt / 32 oz + 1.5 qt	0	98 a	99 a	99 a	87 a	99 a	99 a	99 a	99 a	99 a	64.6 a	1.184 a
Engenia Pro / Flexstar GT + MSO + AMS	16 oz / 3.5 pt + 1 % + 1.5 qt	1	94 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	55.2 j	0.997 hi
Boundary / Flexstar GT + MSO + AMS	1.75 pt / 3.5 pt + 1 % + 1.5 qt	1	94 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	59.4 e-h	1.073 d-g
Surveil / Abundit Edge + Everprex + AMS	3 oz / 32 oz + 1 pt + 3 pt	1	72 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	58.8 gh	1.062 fgh
Afforia / Abundit Edge + Everprex + AMS	2.5 oz / 32 oz + 1 pt + 3 pt	0	67 a	99 a	99 a	99 a	99 a	99 a	85 b	99 a	99 a	59.3 fgh	1.071 d-g
Zidua Pro / Flexstar + Select + MSO + AMS	5 oz / 1 pt + 6 oz + 1 % + 3 pt	1	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a	56.6 hij	1.023 ghi
Post I (4" Weeds)													
Roundup Powermax + AMS	32 oz + 1.5 qt	0	-	99 a	82 b	-	99 a	99 a	-	62 b	54 b	59.4 e-h	1.074 d-g
Liberty 280 + AMS	32 oz + 1.5 qt	0	-	99 a	99 a	-	99 a	99 a	-	16 c	15 c	61.9 a-f	1.132 a-e
Flexstar GT + MSO + AMS	3.5 pt + 1 % + 1.5 qt	1	-	99 a	99 a	-	99 a	99 a	-	97 a	98 a	58.4 ghi	1.055 fgh
Checks													
Liberty Check		-	0 b	0 b	0 c	0 b	0 b	0 b	0 c	0 c	0 c	54.8 j	1 hi
Engenia Check		-	0 b	0 b	0 c	0 b	0 b	0 b	0 c	0 c	0 c	**55.3 ij**	**1 hi**
	LSD (0.10)	1.2	53.9	0.4	15.5	14.4	ns	ns	14.1	29.3	26.3	3.1	0.070

COC = crop oil concentrate; NIS = nonionic surfactant; AMS = liquid spray grade ammonium sulfate.
Yield adjusted to 13% moisture.
Means followed by the same letter do not significantly differ.

Appendix C

The potential impact of volunteer herbicide tolerant soybeans on soybean aphid and soybean cyst nematode populations

Objective

The climate of Minnesota often favors the survival of soybeans left in the field from harvest losses. These seeds can germinate in the spring. These “volunteer” soybeans have the potential to influence soybean pests.

While they broaden the available scope of herbicide tools for the management of hard to control and herbicide resistant weeds, the increasing number of herbicide tolerant traits for soybean can limit options for control of volunteer soybeans.

This study examines the effect of several common corn herbicide programs on the survival of three commonly planted types of herbicide tolerant soybeans and the subsequent effects on the populations of soybean aphid and soybean cyst nematode (SCN).

Site description

University of Minnesota Southwest Research and Outreach Center near Lamberton, Redwood County, MN.

This study was conducted on a Webster clay loam soil containing 4.0% organic matter, pH 6 and soil test P and K levels of 16 and 116 ppm, respectively. A much tiller was used for primary fall tillage of the study area was and 125 pounds N as NH_3 was applied on November 2, 2017. A field cultivator was used for spring tillage.

Methods

On May 16, 2018, Pioneer 0157AMXT corn was planted at 34,000 seeds/acre into 30-inch rows oriented north to south. Three herbicide tolerant soybean varieties were planted at 150,000 seeds/acre in four, 30-inch rows perpendicular to the corn rows. Each variety was replicated four times. The Asgrow AG 1435 RR2 (glyphosate tolerant), Asgrow AG14X8 Xtend (dicamba tolerant), and Croplan LC1864 Liberty Link (glufosinate tolerant) soybean varieties had PI 88788 source SCN resistance.

Eleven corn herbicide treatments (*Table C1*) were applied with the corn rows in plots 4 rows wide by 10-foot long. This design created a 10-foot by10-foot micro-plot for each herbicide X soybean variety treatment. Herbicides were applied with a tractor-mounted sprayer at 15 gpa and 35 psi. The sprayer was equipped with 8002 flat-fan nozzles (pre) and 11002 TT nozzles (post) spaced 15 inches apart on the boom. Pre-emerge

herbicides were applied May 17 and post emerge herbicides were applied to 3rd trifoliate soybeans on June 5.

Soybean stands from the center two rows of soybean in each micro-plot were evaluated on May 30 to evaluate PRE herbicide effects on soybean stand, June 27 to evaluate POST herbicide effects, and August 8 to determine season-long soybean survivorship.

Composite soil samples for soybean cyst nematode (two samples/rep) were taken at a six-inch depth from the center two rows of each soybean micro-plot after planting and after corn harvest. The University of Minnesota Nematology Lab, Waseca, MN, processed the SCN samples.

The experimental design did not allow a way to account for any potential corn yield differences caused by soybean micro-plots.

Results

- Early season soybean colonization by aphids was poor at this location. Aphids arriving in July colonized soybeans plants exposed at the edges of the corn plots but not those underneath the corn canopy. As a result, we were unable to collect soybean aphid data from this study during 2018. However, earlier MSR&PC funded research showed that soybean aphids are able to colonize and reproduce on volunteer soybeans.
- Overall, at-plant spring SCN density averaged 1095 SCN eggs/100 cc soil. However, initial population densities were not uniform across this trial. The southernmost replication had much lower initial densities (313 - 363 eggs/100cc soils) while samples from the remaining replications ranged (550 - 2,825 eggs/100 cc). This variability could be happenstance or possibly a legacy from the planting of more than one variety within this study site during a previous year. *As with most SCN data, this variability makes interpretation of results difficult.*
- Soybean and soybean cyst nematode populations for the three soybean varieties are shown in (Appendices *C i, C ii,* and *C iii*).
- Herbicide tolerant soybeans responded to applications of PRE and POST herbicides as expected with respect to mortality.
- SureStart herbicide (acetochlor + chlorpyralid + flumetsulam) provided better PRE control of all herbicide tolerant soybeans than Dual II (metachlor) or Harness (acetochlor).
- At-plant and end of season SCN population densities were similar where herbicides did not reduce soybean populations.
- ***End of season SCN population densities were generally lowest where PRE herbicides allowed soybeans to survive but POST herbicides produced high mortality.***
- Where soybean survival was highest, the glyphosate tolerant variety had somewhat fewer SCN eggs at end of season than the dicamba or glufosinate tolerant varieties. These data highlight the potential for confounding SCN population density with a soybean variety's SCN resistance and other

genetic/environmental factors. It may be prudent to recognize the importance of these factors when comparing SCN population densities and yield among SCN resistant soybeans varieties.

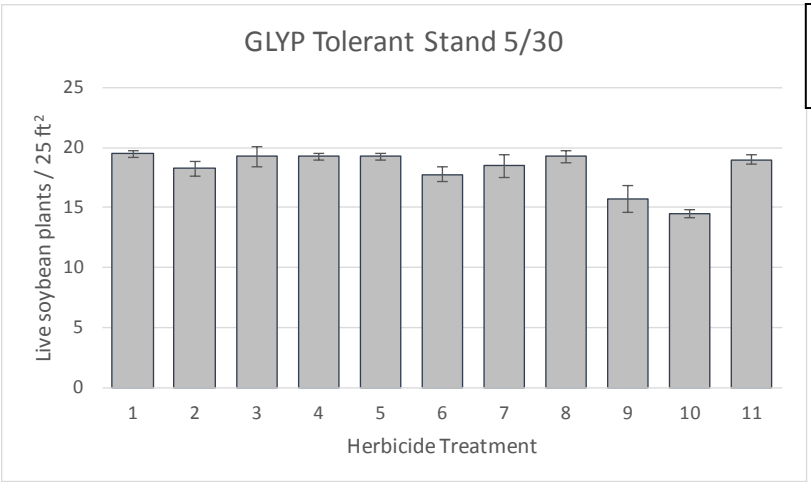
What do these results mean for soybean growers?

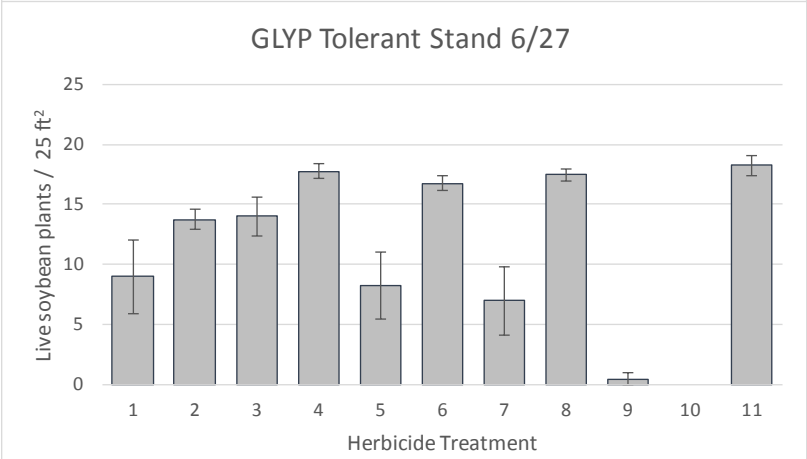
- Soybean varieties with tolerance to multiple herbicides means that corn herbicide selection can influence the populations of volunteer soybeans.
- When volunteer soybean varieties persist within a corn crop season-long, the rotational benefit of a non-host crop year can be reduced for SCN. Although not tested here, volunteer soybeans may serve as a crop rotation-negating green bridge for other pathogens as well.
- Uncontrolled volunteer soybeans have the potential to increase selection pressure against SCN resistance.
- These preliminary data indicate that there is some potential for use of soybeans as a trap crop to reduce SCN populations provided herbicide control of the soybean is well-timed.

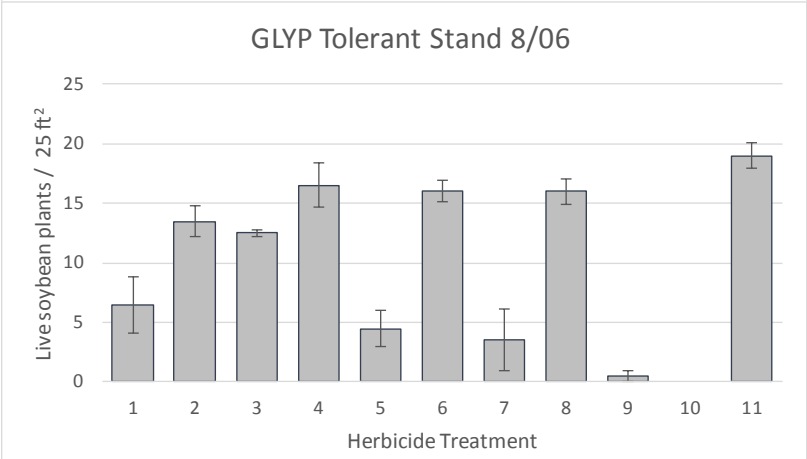
Trt. No.	Product	Rate	Timing	Group
1	Acuron	3 qt/a	PRE	5, 15, 27(2)
2	Dual II Magnum	2 pt/a	PRE	15
	Liberty	22 fl oz/a	POST	10
	AMS	1.5 qt/a	POST	
3	Harness	2.25 pt/a	PRE	15
	Liberty	22 fl oz/a	POST	10
	AMS	1.5 qt/a	POST	
4	Harness	2.25 pt/a	PRE	15
	Cornerstone Plus	32 fl oz/a	POST	9
	AMS	1.5 qt/a	POST	
5	Harness	2.25 pt/a	PRE	15
	Status	5 oz/a	POST	4, 19
	NIS	1 qt/100 gal	POST	
6	Harness	2.25 pt/a	PRE	15
	Callisto	3.6 pt/a	POST	27
	AMS	1.5 qt/a	POST	
7	Harness	2.25 pt/a	PRE	15
	Balance Flexx	6 fl oz/a	POST	27
	Status	5 oz/a	POST	4, 19
	NIS	1 qt/100 gal	POST	
8	Corvus	5.6 fl oz/a	PRE	2, 27
	Cornerstone Plus	32 fl oz/a	POST	9
	AMS	1.5 qt/a	POST	
9	Surestart	2 pt/a	PRE	2, 4, 15
	Cornerstone Plus	32 fl oz/a	POST	9
	AMS	1.5 qt/a	POST	
10	Surestart II	2 pt/a	PRE	2, 4, 15
	Callisto	3.6 pt/a	POST	27
	AMS	1.5 qt/a	POST	
11	Cornerstone Plus	32 fl oz/a	Early POST	9
	AMS	1.5 qt/a	Early POST	
	Cornerstone Plus	32 fl oz/a	Late POST	9
	AMS	1.5 qt/a	Late POST	

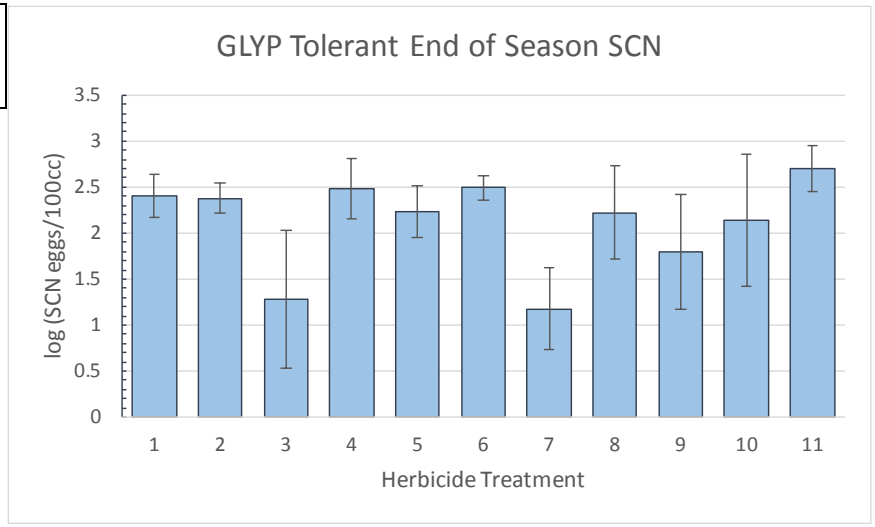
Table C1. Corn herbicide treatments

Appendix
C i









Glyphosate tolerant soybean

TRT	PRE	HERBICIDE POST	30-May PRE Stand Reduced?	27-Jun POST Stand Reduced?	8-Aug Final Stand Reduced?	End of Season SCN Reduced?
1	Acuron				X	
2	Duall II Magnum	Liberty		X	X	
3	Harness	Liberty		*X*	*X*	*X*
4	Harness	Cornerstone Plus		X	X	
5	Harness	Status		X	X	
6	Harness	Callisto			X	
7	Harness	Balance Flexx + Status		*X*	*X*	*X*
8	Corvus	Cornerstone Plus			X	
9	Surestart	Cornerstone Plus	X	X	X	
10	Surestart	Callisto	X	X	X	
11		Cornerstone/Cornerstone				

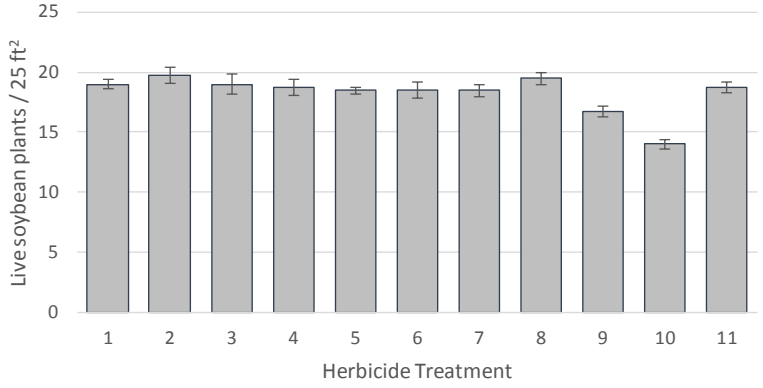
Glyphosate tolerant variety

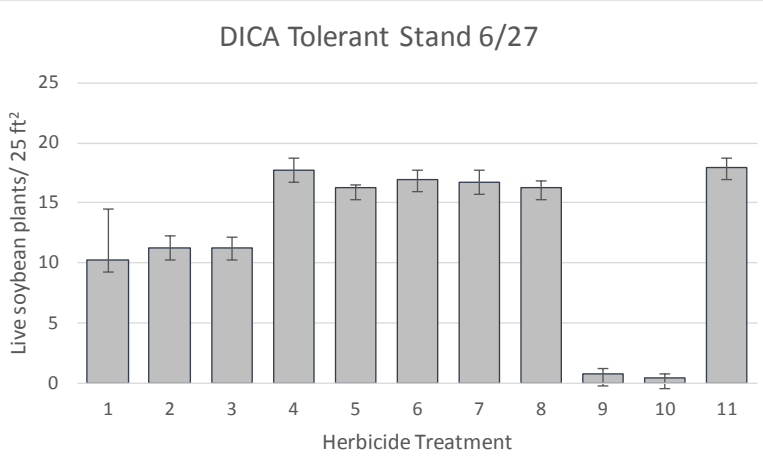
SCN reduced by 3) Harness PRE, Liberty POST and 7) Harness PRE, Balance Flexx+ Status POST*

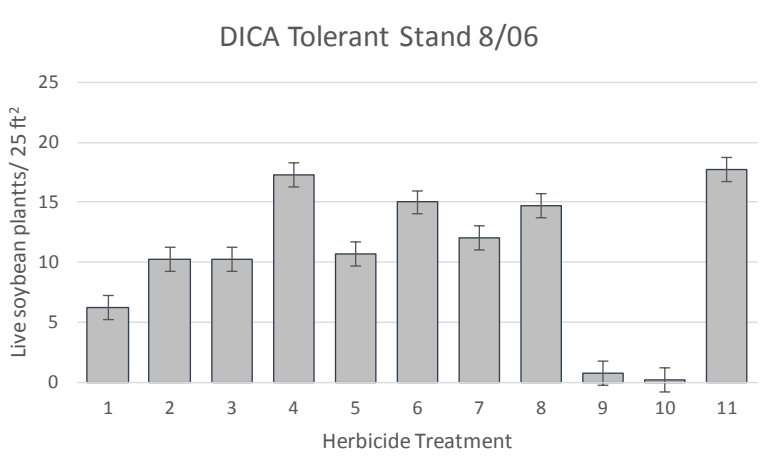
No stand loss: 11 (Cornerstone Plus followed by Cornerstone Plus POST)

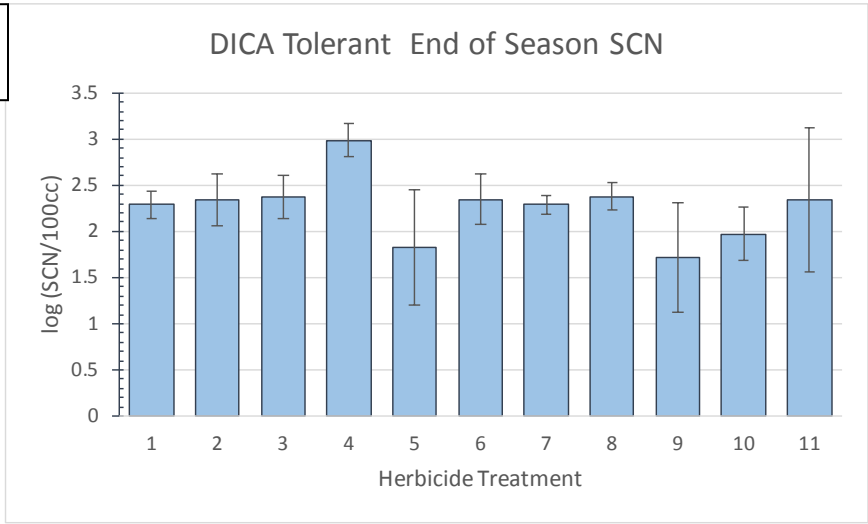
Status alone POST slow soybean kill

Appendix
C ii









Dicamba tolerant soybean

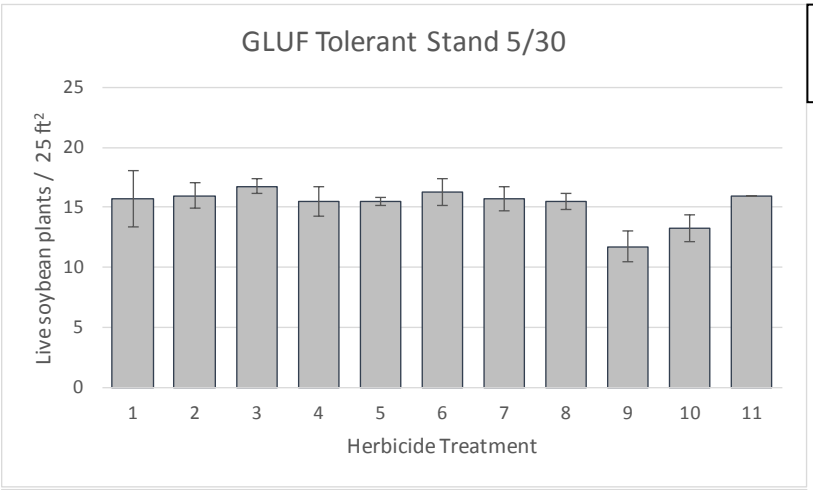
TRT	HERBICIDE PRE	HERBICIDE POST	30-May PRE Stand Reduced?	27-Jun POST Stand Reduced?	8-Aug Final Stand Reduced?	End of Season SCN Reduced?
1	Acuron			X	X	X
2	Duall II Magnum	Liberty		X	X	X
3	Harness	Liberty		X	X	X
4	Harness	Cornerstone Plus				
5	Harness	Status			X	X
6	Harness	Callisto			X	X
7	Harness	Balance Flexx + Status			X	X
8	Corvus	Cornerstone Plus			X	X
9	Surestart	Cornerstone Plus	X	X	X	X
10	Surestart	Callisto	X	X	X	X
11		Cornerstone/Cornerstone				

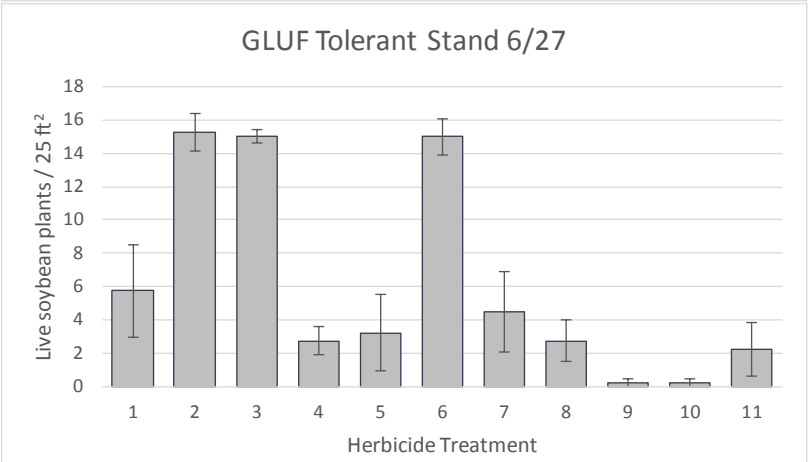
Dicamba tolerant variety

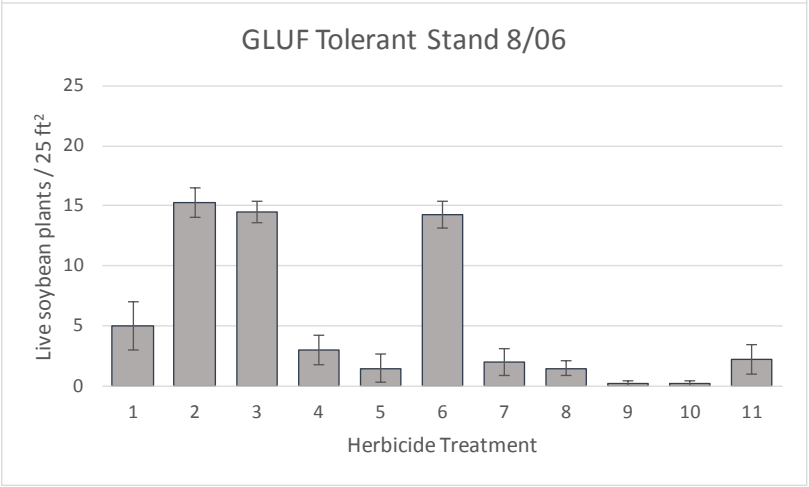
SCN reduced by all herbicide regimes except 4) Harness PRE Cornerstone Plus POST, and 11) Cornerstone Plus/Cornerstone Plus POST

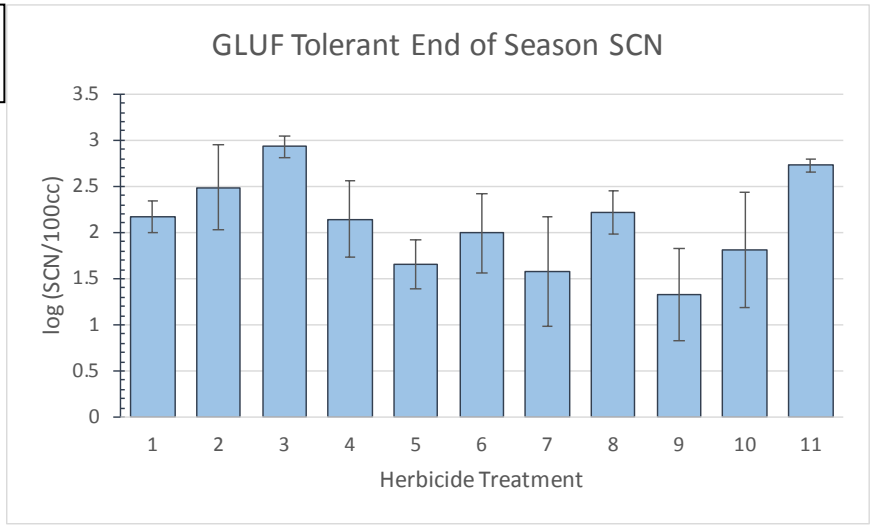
No stand loss: 4) Harness PRE –Cornerstone Plus POST and 11 (Cornerstone Plus/ Cornerstone Plus POST)

Appendix
C iii









Liberty (glufosinate) tolerant soybean

TRT	HERBICIDE PRE	HERBICIDE POST	30-May PRE Stand Reduced?	27-Jun POST Stand Reduced?	8-Aug Final Stand Reduced?	End of Season SCN Reduced?
1	Acuron			X	X	X
2	Duall II Magnum	Liberty				
3	Harness	Liberty				
4	Harness	Cornerstone Plus		X		X
5	Harness	Status		X	X	X
6	Harness	Callisto				X
7	Harness	Balance Flexx + Status		X	X	X
8	Corvus	Cornerstone Plus		X	X	X
9	Surestart	Cornerstone Plus	X	X	X	X
10	Surestart	Callisto	X	X	X	X
11		Cornerstone/Cornerstone		X	X	X

Glufosinate tolerant variety

SCN reduced by all herbicide regimes except 2) Harness PRE Liberty POST, and 3) Harness PRE – Liberty POST and 6) Harness PRE- Halex GT POST

No stand loss: 2) Harness PRE Liberty POST, and 3) Harness PRE – Liberty POST and 6) Harness PRE- Callisto POST