College of Agriculture, Food and Environment

2020 Soybean Science Research Report

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2020 SOYBEAN SCIENCE RESEARCH REPORT

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Efficacy of Foliar Fungicides for Management of Target Spot of Soybean

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OBJECTIVES

The objective of this research was to determine the efficacy of foliar fungicides for control of target spot of soybean (caused by the fungus *Corynespora cassiicola*).

MATERIALS AND METHODS

A field trial was conducted at the University of Kentucky Research & Education Center near Princeton, KY in 2020. The soybean cultivar 'Asgrow 53X0' was planted on May 7. Plots were 4 rows wide (30 inch row spacing) and 20 ft long. Plots were arranged in a randomized complete block design with 4 replications. When soybean plants reached the R3 growth stage (beginning pod development), foliar fungicide treatments were applied with a carbon dioxide-pressurized backpack sprayer calibrated to deliver 20 GPA at 40 PSI pressure. Approximately 6 weeks following treatment applications, plots were rated for target spot severity by estimating the percentage of the mid-canopy soybean leaf area affected by target spot lesions. Plots were harvested with a small plot research combine on November 2, and grain yields were calculated and adjusted to 13% moisture.

RESULTS

Statistically significant differences were detected among treatments for target spot severity and yield (Table 1). All treatments except Topguard EQ, Froghorn, Topsin 4.5 L., and Equus had significantly lower target spot severity ratings than the nontreated control. The lowest target spot severity was achieved with Lucento, which was not significantly different than Miravis Top, Revytek, or Priaxor + Tilt. The only treatments that resulted in yields significantly greater than the nontreated control were Miravis Top and Revytek.

CONCLUSIONS AND IMPLICATIONS

Target spot is an emerging disease of soybean that has been increasing its presence in the southern U.S. in recent years. Results from our trial indicate that some fungicide products are able to provide some efficacy against target spot. In general, fungicides that contain an active ingredient in the succinate dehydrogenase inhibitor (SDHI) fungicide class tended to provide the best control of target spot. In our trial, Headline fungicide, which contains only a quinone outside inhibitor (QoI; also known as strobilurin) active ingredient provided control of target spot; however, it is important to note that resistance to QoI fungicides in the target spot fungus was recently reported in Alabama (Nunes Rondon and Lawrence 2019). Therefore, it is important to use a fungicide product that contains active ingredients from at least two efficacious fungicide groups or to tank mix fungicides from at least two groups to help slow down the development of fungicide resistance in the target spot fungus in Kentucky.

ACKNOWLEDGEMENTS

This project was funded by the Kentucky Soybean Promotion Board and FMC. We also thank Alissa Gott and Nathan White for their assistance with this project.

Table 1. Effect of foliar fungicides applied at the R3 growth stage on target spot severity and soybean yield in Princeton, KY in 2020.

Treatment	Rate (fl oz/A)	Target spot severity (%)	Yield (bu/A)
Nontreated	-	20.0 A*	66.2 C*
Topguard EQ	5	16.3 AB	69.2 BC
Lucento	5	5.5 F	69.7 BC
Miravis Top	13.7	6.8 EF	78.3 A
Revytek	8	6.8 EF	75.1 AB
Delaro	8	15.0 BC	66.8 C
Headline	6	11.3 CD	66.4 C
Priaxor + Tilt	4+4	6.0 F	65.7 C
Trivapro	13.7	10.0 DE	69.2 BC
Acropolis	20	15.0 BC	70.6 BC
Froghorn	20	17.5 AB	71.4 BC
Topsin 4.5 L	20	17.5 AB	68.7 BC
Aproach Prima	6.8	15.0 BC	67.0 C
Equus	36	20.0 A	70.1 BC

*Target spot severity values or yields followed by the same letter are not significantly different according to the statistical analysis (95% confidence).

Evaluation of Nematode Protectant Seed Treatments on Soybean in Fields Infested with Soybean Cyst Nematode in Kentucky

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OBJECTIVES

The objective of this research was to evaluate the effect of nematode protectant seed treatments on soybean plant stand and yield in fields infested with soybean cyst nematode (SCN; *Heterodera glycines*).

MATERIALS AND METHODS

Field trials were conducted in Caldwell County (at the University of Kentucky Research & Education Center near Princeton, KY) and in Daviess County (on a farmer's field near Owensboro, KY) in 2020. Both fields were infested with SCN, where the populations at planting averaged 9,335 SCN eggs/100 cc soil at the Caldwell County field and 12,283 egg/100 cc soil at the Daviess County field. The Caldwell County field had been planted to soybean the previous year and the Daviess County field had been planted to corn the previous year. Seeds of 'Progeny 4444 RXS' were planted at 135,000 seeds/A with a Kincaid Voltra precision research planter on May 5 and May 25 at the Caldwell County and Daviess County fields, respectively. Plots were 4 rows wide (30 inch row spacing) and 20 ft long, and were arranged as a randomized complete block design with 6 replications at each field. Seeds were treated with the following products:

- Non-treated seed
- "Base treatment" which included Allegiance FL + Stamina + Systiva XS Xemium Brand, + Poncho 600
- Saltro + Base
- Votivo + Base
- ILEVO + Base
- Clariva + Base
- Clariva + Saltro + Base
- Aveo
- BioST
- Trunemco

At approximately 2 weeks after planting, plant stands were evaluated by counting the number of emerged plants in a 10 ft long section of the two middle rows of each plot. Plots were harvested with a small plot research combine equipped with a research grain gauge used to measure the weight and moisture of the harvested grain of each plot. The trial at Caldwell County was harvested on October 5 and the trial at Daviess County was harvested on November 6.

RESULTS

No statistically significant differences were detected among treatments for plant stand or soybean yield at either location. Plant stands ranged from 71,293 to 88,137 plants/A and 105,415 to 111,949 plants/A at the Caldwell County and Daviess County fields, respectively (Table 1). Yields ranged from 69.1 to 75.6 bu/A and 68.9 to 76.2 bu/A at the Caldwell County and Daviess County fields, respectively.

CONCLUSIONS AND IMPLICATIONS

Soybean cyst nematode is the most important pathogen of soybean in Kentucky regarding yield loss every year, and management of this pathogen is important for sustaining high yields. The most important steps in managing SCN is to test fields to know the SCN egg populations, grow resistant varieties, and rotate to non-host crops. If these three management practices are being done and SCN populations do not decrease over time, then considering using a nematode protectant seed treatment might be the next step in providing additional management of SCN. The SCN populations in the fields in which we conducted the research trials were high to very high. These high SCN populations may have overcome any effect that the seed treatments might have otherwise provided in fields with lower SCN populations. At the time this report was written, we did not yet have the results of soil testing to determine the SCN egg populations at harvest, which will be used to determine SCN reproduction during the season. Effective nematode protectant seed treatments may reduce SCN reproduction during the growing season. Overall, more testing in fields with varying SCN populations is needed to better determine the impact of nematode protectant seed treatments on soybean plant stand and yield in Kentucky.

ACKNOWLEDGEMENTS

This project was funded by the Kentucky Soybean Promotion Board and BASF. We thank Fischer CrossCreek Farms for allowing us to conduct research on their farms. We also thank Alissa Gott and Nathan White for their assistance with this project.

Table 1. Effect of nematode protectant seed treatments on soybean plant stand and soybean yield at two fields in Kentucky (Caldwell County, and Daviess County) in 2020.

	Caldwell County		Daviess County	
Treatment	**Stand (plants/A)**	**Yield (bu/A)**	**Stand (plants/A)**	**Yield (bu/A)**
Non-treated	71,293	70.5	107,303	68.9
Base treatment*	88,137	70.3	105,415	75.2
Saltro + Base	79,570	69.1	111,949	72.1
Votivo + Base	82,764	72.2	107,593	72.2
ILEVO + Base	78,844	72.1	108,900	75.6
Clariva + Base	84,216	69.7	108,755	73.0
Clariva + Saltro + Base	87,411	70.5	111,514	72.8
Aveo	82,328	73.0	109,481	74.9
BioST	79,860	75.6	108,174	76.2
Trunemco	83,490	70.3	108,610	75.3
LSD 0.05**	**NS*****	**NS**	**NS**	**NS**

*Base fungicide + insecticide treatment
**Least significant difference
***No statistically significant differences within a column

Efficacy of Foliar Fungicides for Management of Frogeye Leaf Spot of Soybean

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OBJECTIVES

The objective of this research was to determine the efficacy of foliar fungicides for control of frogeye leaf spot of soybean (caused by the fungus *Cercospora sojina*).

MATERIALS AND METHODS

A field trial was conducted in Union County, KY in 2020. The soybean cultivar 'Pioneer 48A60X' was planted on June 19. Plots were 4 rows wide (15 inch row spacing) and 20 ft long. Plots were arranged in a randomized complete block design with 4 replications. When soybean plants reached the R3 growth stage (beginning pod development), foliar fungicide treatments were applied with a carbon dioxide-pressurized backpack sprayer calibrated to deliver 20 GPA at 40 PSI pressure. Approximately 4 weeks following treatment applications, plots were rated for frogeye leaf spot severity by estimating the percentage of the soybean leaf area affected by frogeye leaf spot lesions. Plots were harvested with a small plot research combine on November 7 and grain yields were calculated and adjusted to 13% moisture.

RESULTS

Statistically significant differences were detected among treatments for frogeye leaf spot severity but not for yield (Table 1). All treatments except Headline had significantly statistically significant lower frogeye leaf spot severity ratings than the nontreated control. The lowest frogeye leaf spot severity rating was achieved with Lucento, which was not significantly different than Revytek or Miravis Top.

CONCLUSIONS AND IMPLICATIONS

Frogeye leaf spot is an important disease of soybean in Kentucky and surrounding states. Since 2010, strains of the frogeye leaf spot fungus with resistance to quinone outside inhibitor (QoI; a.k.a. strobilurin) fungicides have been known to occur in Kentucky. With no control of frogeye leaf spot being achieved with Headline fungicide, which is a QoI fungicide, in this trial, QoI-resistant strains were obviously present in this field. All fungicide treatments tested, except Headline, effectively reduced frogeye leaf spot severity in this trial. Interestingly, the three best treatments for frogeye leaf spot control contained fungicide active ingredients from both demethylation inhibitor (DMI; a.k.a. triazole) and succinate dehydrogenase inhibitor (SDHI) fungicide classes. With QoI-resistance being widespread, it is important to choose a fungicide product that contains multiple active ingredients from chemistry classes that are still effective in controlling frogeye leaf spot.

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This project was funded by the Kentucky Soybean Promotion Board. We thank Scates Farms for allowing us to conduct research on their farm. We also thank Alissa Gott and Nathan White for their assistance with this project.

Table 1. Effect of foliar fungicides applied at the R3 growth stage on frogeye leaf spot severity and soybean yield in Union County, KY in 2020.

Treatment	Rate (fl oz/A)	Frogeye leaf spot severity (%)	Yield (bu/A)
Nontreated	-	13.4 B*	73.2 A*
Headline	6	17.5 A	73.2 A
Delaro	8	5.3 DE	75.4 A
Priaxor + Tilt	4+4	8.0 C	73.0 A
Domark	4	7.1 CD	72.7 A
Topsin 4.5 L	20	4.6 E	72.3 A
Miravis Top	13.7	1.8 F	76.3 A
Revytek	8	2.9 EF	77.8 A
Lucento	5	1.0 F	73.9 A
Trivapro	13.7	8.2 C	75.9 A

*Frogeye leaf spot severity values or yields followed by the same letter are not significantly different according to the statistical analysis (95% confidence).

Evaluation of Multiple Site of Action Residual Herbicide Application Timing for Maximum Late Season Waterhemp Control

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INTRODUCTION

Prior to the year 2000 the presence of Palmer amaranth (*Amaranthus palmeri*) and waterhemp (*Amaranthus tuberculatus* [syn *rudis*]) was limited to a few localized areas of west Kentucky. A survey of county extension agents in 2015 and follow-up reports through 2019 confirmed glyphosate-resistant Palmer amaranth in more than 60 counties and waterhemp in 48 counties that extend from west Kentucky eastward to counties within the central parts of Kentucky including counties northeast of Lexington. Since those earlier surveys, glyphosate-resistant waterhemp has continued to spread into more crop fields and become a major problem for many Kentucky soybean growers. In addition to glyphosate-resistance, there was evidence in 2012 indicating ALS-resistance was present in both species in Kentucky. Plant tissue samples collected in 2015 and 2017 submitted to the University of Illinois for DNA analysis indicated PPO-resistant Palmer amaranth and waterhemp populations were present in Kentucky and have continued to spread.

In order to limit the development and spread of weeds with multiple herbicide resistance, weed scientists emphasize the need to diversify cultural practices and choice of herbicide programs that offer multiple effective sites of action (Multiple-SOA). Earlier trials conducted in west Kentucky showed that soil-residual herbicides with only a single effective site of activity averaged less than 15% control as compared to soil-applied herbicides with two sites of effective activity averaging 35% control; and improved to nearly 60% control when soil residual herbicides with three effective sites of action were applied. Additional studies in 2017, 2018, and 2019 looking at complete herbicide programs in multiple herbicide tolerant soybean systems consistently showed that programs with soil residuals with three effective sites of action resulted in greater *Amaranthus* control as compared to programs with a single effective site of action soil residuals or lacking a soil residual.

This research continues to back the message of weed scientists that use of a soil residual herbicide with multiple effective sites of action is the best tool for *Amaranthus* control, regardless of soybean herbicide tolerance and postemergence herbicide packages. Despite this overwhelming evidence, growers tend to cut back on residual herbicides especially with the recent influx of new herbicide-tolerant soybean traits that include Roundup Ready 2 Xtend (dicamba and glyphosate tolerance), Enlist E3 (2,4-D, glyphosate, and glufosinate tolerance), Liberty Link GT27 (glyphosate, glufosinate, and HPPD tolerance), and XtendFlex (glyphosate, glufosinate, and dicamba tolerance) all of which offer effective postemergence control of *Amaranthus.*

The decision of farmers to cut back on soil residuals or use only a single effective SOA (Single-SOA) residual herbicide versus a multiple-SOA residual often comes down to added crop production cost. Multiple-SOA residuals typically cost about $20 to $30 per acre and are significant investments, as compared to single-SOA residual which are about half the cost at $10 to $18 per acre.

University of Kentucky Weed Scientist have observed late season *Amaranthus* escapes on multiple farmer fields where single-SOA residuals were followed by one to two applications of an effective postemergence herbicide (i.e. dicamba, 2,4-D, or glufosinate). While these late season escapes are usually sporadic throughout the field, they do produce seed that continues to build back the soil seed bank for future generations and are more than likely spread by harvesting equipment.

OBJECTIVE

Conduct research at waterhemp (*Amaranthus tuberculatus*) infested locations to evaluate timing of herbicide application with multiple residual sites of action in comparison to single site of action residuals and their influence on late season waterhemp control.

MATERIAL AND METHODS

Experiments were established on grower locations with known infestations of waterhemp in Taylor and Caldwell County. A Roundup Ready 2 Xtend soybean variety was planted at 140,000 seeds per acre on June 12, 2020 at Caldwell County. The Taylor County site was planted to an Enlist E3 soybean variety at 160,000 seeds per acre on June 2, 2020.

The experimental design was a randomize complete block with four replications, plots measured 10 ft wide by 30 ft in length. Treatments were included within these four herbicide residual application programs:

- **Multi-SOA Pre fb Layby:** Multiple-SOA preemergence followed by a single-SOA residual applied postemergence
- **Multi-SOA Pre:** Multiple-SOA applied preemergence only
- **Single SOA Pre fb Layby:** Single-SOA preemergence followed by a single SOA residual applied postemergence
- **Single SOA Pre:** Single-SOA applied preemergence only

Specific residual herbicide, active ingredients, and application timing are listed in Table 1. All treatments received an application containing either Roundup PowerMax plus Xtendimax or Liberty to control emerged waterhemp plants at the time of postemergence application at Caldwell and Taylor County, respectively.

Visual evaluations of waterhemp control four weeks after preemergence and four weeks after postemergence applications were taken, as well visual evaluations at soybean harvest. Waterhemp density per 75 ft^2 was taken prior to soybean harvest.

RESULTS

Waterhemp control four weeks after the final postemergence application ranged from 58 to 100 percent control at Caldwell County and 73 to 98 percent control at Taylor County (Table 2). Differences at Caldwell county occurred with Canopy applied preemergence with no layby residual having significantly lower control as compared to all other treatments. Authority XL applied preemergence with no layby had significantly less waterhemp control than all treatments with multiple sites of action, with the exception of Canopy followed by Dual II Magnum (Table 2). At Taylor county the only differences occurred between Fierce XLT (multiple effective sites of action) applied preemergence and Canopy (single effective site of action) applied preemergence, with Canopy having significantly less control of waterhemp.

Waterhemp densities at harvest ranged from 0 to 94 plants per 75 ft^2 at Caldwell County and 0 to 12 plants per 75 ft^2 at Taylor County (Table 3). In comparison, the density of waterhemp per 75 ft^2in the Untreated was 237 and 37 in Caldwell and Taylor County, respectively. Thus, all treatments reduced the waterhemp density significantly as compared to the untreated. Waterhemp densities at harvest at Caldwell county were significantly greater in the Canopy applied preemergence treatment as compared to all other treatments, regardless of timing or number of residual sites of action (Table 3). The Taylor county waterhemp density at harvest differed between Fierce XLT applied preemergence and Canopy applied preemergence, with Fierce XLT having a significantly lower waterhemp density than Canopy (Table 3).

Evaluation of herbicide residual programs showed that differences in the residual program approach occurred at the Caldwell County site (Table 4). Densities at soybean harvest were significantly higher in the single SOA pre approach as compared to all other programs in which multiple residual sites of action were applied at Caldwell County (Table 4). In contrast no statistical differences in residual herbicide programs occurred at Taylor County when evaluating waterhemp density at soybean harvest (Table 4).

In summary of these results, the short term benefits of using multiple residual herbicide sites of action were not obvious within this research as at both sites the use of a couple of single site of action residuals resulted in similar waterhemp densities at the end of the season as compared to treatments with multiple sites of action. Although, when looking at an end of season waterhemp density from a program approach it was evident that multiple residual sites of action was beneficial at the Caldwell County site where waterhemp densities were significantly greater overall as compared to the Taylor County site. At both sites the use of Canopy alone as a residual herbicide did not result in acceptable season long waterhemp control, and thus the use of additional residual sites of action were needed.

These results were collected over a single year and thus do not represent the long-term outcomes of the use residual herbicides with multiple sites of action. It must be noted that long term herbicide resistance management includes using multiple sites of action not only within the entire herbicide program, but within the residual herbicide program. The short-term benefits of multiple residual site of action programs are not always obvious in a single year, as observed the Taylor County site, but weed management, and more specifically waterhemp management, must be approach from a long-term goal perspective rather than short term.

Table 1. Residual herbicide programs, herbicide trade names, active ingredients, and effective residual sites of action.

Program[a]	Preemergence Residual	Postemergence Residual[b]	Effective Residual Sites of Action[c]
Multi SOA Pre *fb* Layby	9 oz Trivence (*0.07 lb flumioxazin + 0.25 lb metribuzin + 0.02 lb chlorimuron*)	1.5 qt Warrant (*1.125 lb acetochlor*) or 1.33 pt Dual II Magnum (*1.27 lb S-metolachlor*) or 3.25 fl oz Zidua SC (*0.11 lb pyroxasulfone*)	3
Multi SOA Pre	4.5 oz Fierce XLT (*0.07 lb flumioxazin + 0.09 lb pyroxasulfone + 0.02 lb chlorimuron*)	-	2
	2 pt Boundary (*1.31 lb S-metolachlor + 0.31 lb metribuzin*)	-	2
	25 fl oz Broadaxe XC (*0.14 lb sulfentrazone + 1.26 lb S-metolachlor*)	-	2
Single SOA Pre *fb* Layby	3.75 oz Valor XLT (*0.07 lb flumioxazin + 0.02 chlorimuron*)	3.25 fl oz Zidua SC (*0.11 lb pyroxasulfone*)	2
	6 oz Canopy (*0.24 lb metribuzin + 0.04 lb chlorimuron*)	1.33 pt Dual II Magnum (*1.27 lb S-metolachlor*)	2
	6.5 oz Authority XL (*0.25 lb sulfentrazone + 0.03 lb chlorimuron*)	1.33 pt Dual II Magnum (*1.27 lb S-metolachlor*)	2
Single SOA Pre	3.75 oz Valor XLT (*0.07 lb flumioxazin + 0.02 chlorimuron*)	-	1
	6 oz Canopy (*0.24 lb metribuzin + 0.04 lb chlorimuron*)	-	1
	6.5 oz Authority XL (*0.25 lb sulfentrazone + 0.03 lb chlorimuron*)	-	1

[a] *fb* = followed by

[b]Postemergence applications included Roundup PowerMax plus Xtendimax at Caldwell County. Postemergence applications at Taylor County included Liberty

[c]Chlorimuron [SOA Group 2] is not considered as an effective site of action due to widespread ALS-inhibitor resistance in Kentucky waterhemp populations.

Table 2. Influence of residual herbicides on waterhemp Control Four Weeks After Postemergence Application.

Program	Preemergence Residual	Postemergence Residual	Caldwell County	Taylor County
			------------- % Control[a]	-------------
Multi SOA Pre fb Layby	Trivence	Warrant	98 A	90 ab
		Dual II Magnum	100 A	83 ab
		Zidua SC	100 A	90 ab
Multi SOA Pre	Fierce XLT	-	96 A	98 a
	Boundary	-	100 A	86 ab
	Broadaxe XC	-	99 A	90 ab
Single SOA Pre fb Layby	Valor XLT	Zidua SC	99 A	90 ab
	Canopy	Dual II Magnum	89 AB	75 ab
	Authority XL	Dual II Magnum	99 A	88 ab
Single SOA Pre	Valor XLT	-	78 AB	80 ab
	Canopy	-	58 C	73 b
	Authority XL	-	78 B	78 ab

[a] Means within a column followed by a different letter are significantly different. Tukey HSD α =0.05

Table 3. Influence of residual herbicides on waterhemp density at soybean harvest.

Program	Preemergence Residual	Postemergence Residual	Caldwell County	Taylor County
			------------ AMATA / 75 ft^2[a,b]-----------	
Multi SOA Pre fb Layby	Trivence	Warrant	0 B	3 ab
		Dual II Magnum	1 B	3 ab
		Zidua SC	0 B	2 ab
Multi SOA Pre	Fierce XLT	-	6 B	0 b
	Boundary	-	0 B	5 ab
	Broadaxe XC	-	0 B	2 ab
Single SOA Pre fb Layby	Valor XLT	Zidua SC	1 B	2 ab
	Canopy	Dual II Magnum	11 B	8 ab
	Authority XL	Dual II Magnum	1 B	3 ab
Single SOA Pre	Valor XLT	-	34 B	5 ab
	Canopy	-	94 A	12 a
	Authority XL	-	21 B	5 ab

[a] Means within a column followed by a different letter are significantly different. Tukey HSD α =0.05
[b] Caldwell County untreated waterhemp density= 237 plants/75 ft^2. Taylor County untreated waterhemp density = 37 plants/75 ft^2.

Table 4. Influence of residual herbicide programs on waterhemp density at soybean harvest.

Program	Caldwell County	Taylor County
	------------- AMATA / 75 ft^2------------	
Multi SOA Pre fb Layby	1 B	3 a
Multi SOA Pre	2 B	2 a
Single SOA Pre fb Layby	4 B	4 a
Single SOA Pre	49 A	7 a

[a] Means within a column followed by a different letter are significantly different. Tukey HSD α =0.05
[b] Caldwell County untreated waterhemp density= 237 plants/75 ft^2. Taylor County untreated waterhemp density = 37 plants/75 ft^2.

Response of the Japanese beetle to pyrethroids in soybeans

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INTRODUCTION

The Japanese beetle, *Popillia japonica* (Coleoptera: Scarabaeidae), is an invasive species detected for the first time in the Northeast U.S. around the 1910's. Nowadays, it is widespread in 28 states. Japanese beetles were found in Kentucky for the first time in 1937. Large numbers of adult Japanese beetles emerge from the ground in early June in Kentucky, then in late July, populations begin to decrease with some individuals still found as late as October (personal observation). Adults can live between 30 to 45 days. During that period they defoliate many plant species, and damage fruit and flowers. After mating, eggs are laid in the soil. The larval forms of this insect are called white grubs, which live underground, feeding on roots of many grasses before overwintering. Pupation occurs between mid-May and mid-July. They are univoltine (one generation per year) species. There are several scarabaeid species within this group that have similar types of activity such as: June bugs, Masked chafer, or June beetles. Japanese beetles can cause damage to more than 300 plant species including many fruit crops, vegetables and ornamentals, as well as soybean and corn.

In soybeans, adult Japanese beetles feed on tissue between secondary leaf veins (Figure 1), which can give rise to skeletonized leaves when the levels of infestations are high. This damage has been more notorious in recent years. In fact severe injuries are reported in other states where soybeans are grown. Japanese beetles also feed on corn silk reducing the formation of kernels.

Figure 1. Japanese beetle damage: Leaf tissue between secondary veins is voraciously eaten, with the subsequent exposure of the primary and secondary veins. (Photo credits: R.T. Villanueva)

OBJECTIVES

This study is aimed to evaluate the efficacy of pyrethroids against Japanese beetles in bioassays conducted in the laboratory.

MATERIALS AND METHODS

Two bioassays were conducted to evaluate the efficacy of two dual mode of action insecticides (Leverage® 360 and Hero®), and three pyrethroids (Baythroid® XL, Warrior® II with Zeon® Technology, and Mustang Maxx®). Insecticide information, rates and bioassays are listed in Table 1.

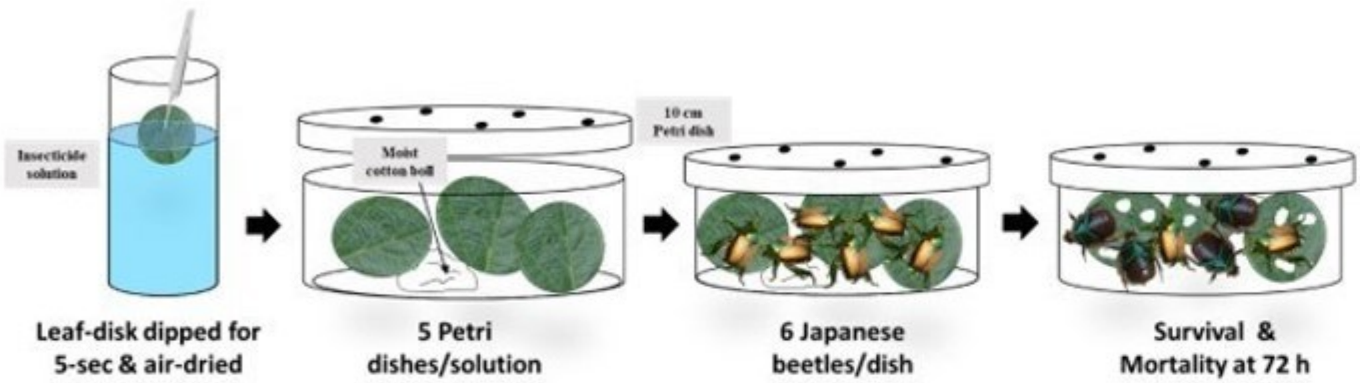
Table 1. Insecticides tested in the first and second bioassays.

Trade Name Manufacturer	% of Active Ingredients	Recommended rate (fl. oz.)	Rate used	First bioassay	Second bioassay
Leverage® 360 (Bayer™ Co.)	*Imidacloprid (21%) & βζ-cyfluthrin (10.5%)*	2.4 to 2.8 fl oz/A	**2.6 fl. oz.**	✓	✗
Hero® (FMC)	*Z-cypermethrin (3.75%) & Bifenthrin (11.25%)*	2.6 to 6.1 oz/A	**4.4 fl. oz.**	✓	✗
Baytrhoid® XL (Bayer™ Co.)	*β-cyfluthrin (12.7%)*	0.8 to 0.16 fl oz/A	**0.12 fl. oz.**	✓	✓
Warrior® II with Zeon® (Syngenta™)	*λ-cyhalothrin (22.8%)*	1.28 to 1.92 fl oz/A	**1.6 fl. oz.**	✓	✓
Mustang Maxx (FMC™)	*Z-cypermethrin (9.15%)*	2.8 to 4.0 fl oz/A	**3.4 fl. oz.**	✓	✓
Control	Water	-	-	✓	✓

In the first bioassay, a leaf disk (3 cm diam) was placed in a petri dish (10 diam x 1 (height) cm) along with seven beetles. Leaf disks were collected at days 3, 4 and 5 from field grown plants that were sprayed with insecticide treatments 3 days earlier (see Table 1). After 24 h, the same set of beetles were fed with new leaf disks [4-DAS (days after spray)] collected from the corresponding sprays sites and left for 24 h; at this point the same JB were kept for 48 h on treated leaves from corresponding treatment of Table 1. The same procedure was conducted with leaves collected 5-DAS and placed with the same beetles (72 h). We measured the effect of insecticide exposure time on Japanese beetles for a maximum period of 3 d. After 24 hours of fresh leaf supply, beetle mortality and leaf damage were recorded. Leaf damage was an estimation of the consumed leaf area percentage. Five petri dishes were set per treatment.

In the second test, unlike the previous bioassay, beetles were exposed immediately to insecticide-treated leaves. Insecticide solutions were prepared according to the recommended field rates. Soybean leaves were collected from a field that was not sprayed. Three-cm leaf disks, which were dipped in the corresponding insecticide solutions for 5 seconds were used. Afterwards, leaf disks were placed on a piece of paper towel until completely dry before placing them in a petri dish. A piece of moist cotton pad was placed on the bottom of the petri dish. Percentages of mortalities were tallied every day for 72 h (Figure 2). Six petri dishes were set per treatment.

Figure 2. Diagram of pyrethroid efficacy against Japanese beetles in soybeans for second bioassay.



RESULTS

In the first experiment, Japanese beetle mortalities were not observed at 24 h after feeding on leaves treated with any of the insecticides. The highest mortalities were recorded for the insecticides with dual mode of action, Hero (38.1%) and Leverage® (19.1%), whereas Warrior®II and Mustang®Maxx showed mortalities below 10%. No dead beetles were observed when leaves were treated with Baythroid (Figure 3). The highest percentages of leaf con-sumption were observed on Baythroid® and Warrior® at 72 h. In Mustang®Maxx, leaf consumption was above 60% after 72 h (Figure 4). Mean percentages of leaf consumption for Hero and Leverage were lower than 20% across all times tallied (24, 48 and 72 h), see Figures 4 and 5.

In the second test, unlike the previous bioassay, beetles were exposed immediately to insecticide-treated leaves. Insecticide solutions were prepared according to the recommended field rates. Soybean leaves were collected from a free insecticide field. A borer was used to cut out three-cm leaf disks, which were dipped in the corresponding insecticide solutions for 5 seconds. Afterwards, leaf disks were placed on a piece of paper towel until completely dry before placing them in a petri dish. A piece of moist cotton pad was placed on the bottom of the petri dish. Percentages of mortalities were tallied every day for 72 h (Figure 3). Six petri dishes were set per treatment.

Figure 3. Mean (±SEM) mortality percentages of Japanese beetles after feeding on insecticide sprayed soybean leaves collected 3 (24 h), 4 (48 h), and 5 (72 h) after the field spray.

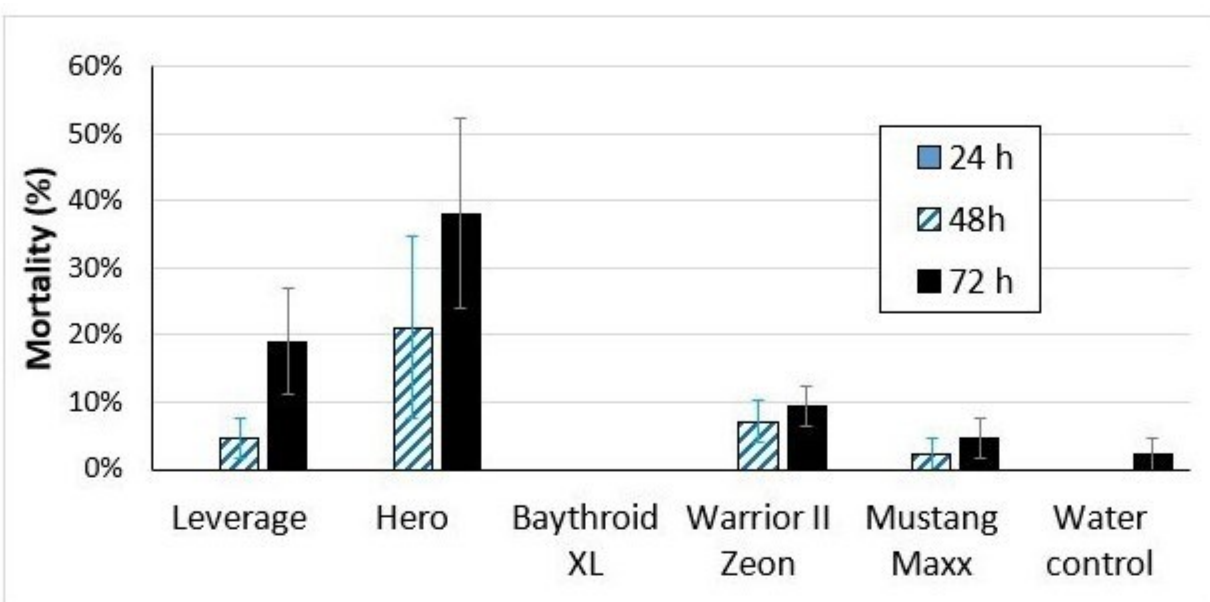


Figure 4. Mean (±SEM) leaf consumption percentages by Japanese beetles after feeding on insecticide sprayed soybean leaves collected 3 (24 h), 4 (48 h), and 5 (72 h) after the field spray.

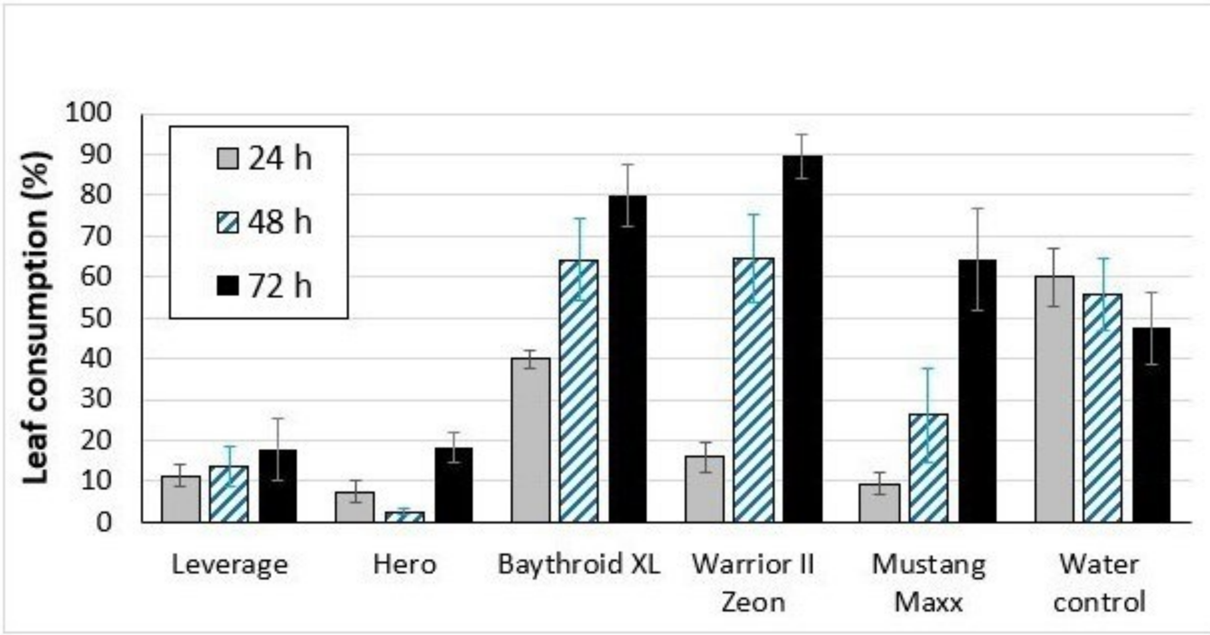


Figure 5. Leaf consumption by Japanese beetles on leaves collected 4 (left) and 5-days (right) after spray with the respective insecticides. The same Japanese beetles in this study were feed with leaves collected 3, 4 and 5 day for 24 h each. (Read Materials and Methods section).

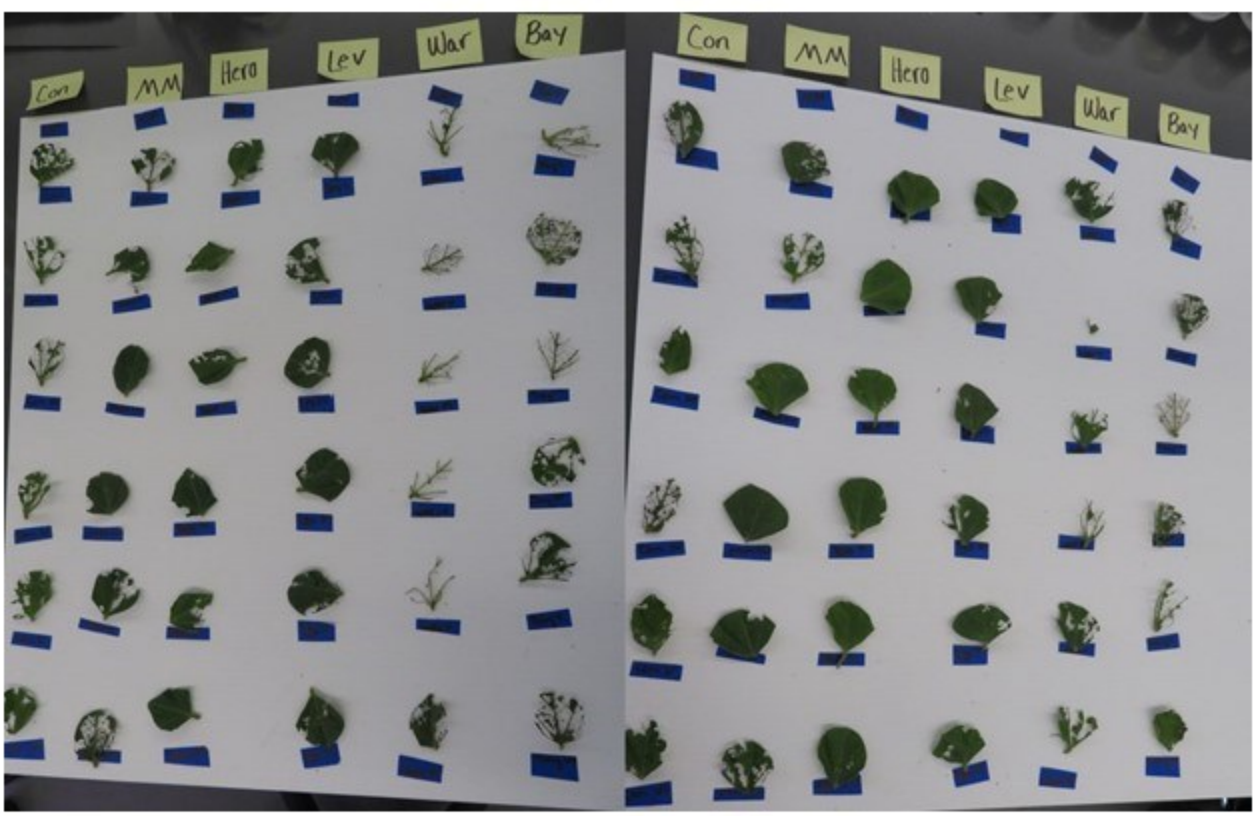
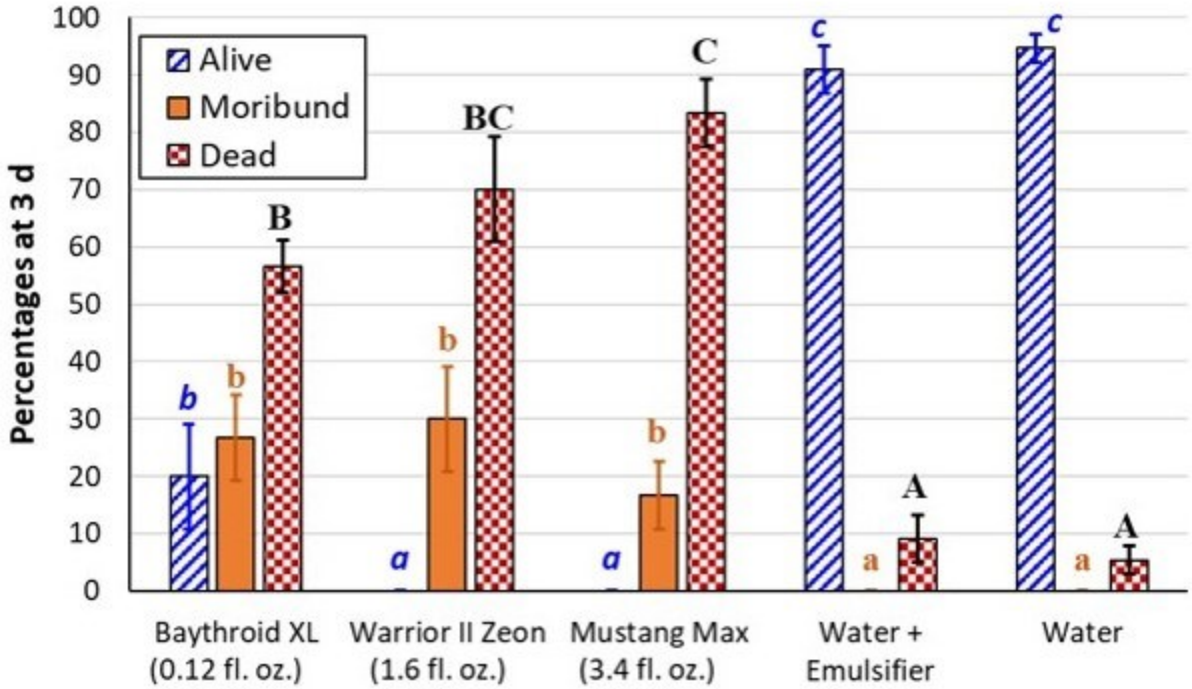


Figure 6. Percentages of alive, moribund or dead Japanese beetles at day 3 after insecticide treatment.



DISCUSSION

The double mode of action insecticides (Leverage® and Hero®) were more efficient in causing high per- cent- ages of Japanese beetle mortalities than pyrethroids (Figures 3); therefore, reducing defoliation. These defolia- tion levels would be considered below the economic defoliation threshold for Japanese bee- tles in soybean plants; <30% before bloom and <20% from bloom to pod (Turnipseed, 1972; Shanovich et al. 2019). The effec- tiveness of the pyrethroids Baythroid®, Warrior®II with Zeon Technology, and Mus- tang®Maxx were of short dura-tion. Cumulated mortalities of Japanese beetles fed with disk leaves 3, 4, and 5 d after the spray were between 0% (Baythroid®) to near 10% (Warrior® II) (Figures 3).

In the second bioassays, the pyrethroid Mustang®Maxx, resulted in the highest mortality [83.3%±5.8 (mean SEM)] of Japanese beetle 3 d after exposure to treated leaf disks (Figures 6). Baythroid®, Warrior® II with Zeon Technology mortalities were below 70%. In both bioassays, single mode of action pyrethroids were not effective against Japanese beetles and Baythroid was the least effective. Further studies will be completed to confirm these results.

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Foliar Fertilizers Did Not Affect Soybean Yields in 2020

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Farmers are always interested in finding more ways to improve yields. Foliar fertilizers are marketed to increase yields and often added to the tank during other applications.

We tested several commercial products in Kentucky to observe their effect on soybean yield in 2020. Full season soybeans were planted at Princeton and Lexington with target stands above 100,000 plants per acre. Soils were amended according to soil tests and University of Kentucky guidelines. Pests were managed well. Foliar products were applied at the R3 growth stage (beginning pod set). Yields averaged 69 and 74 bushels per acre at Princeton and Lexington, respectively. None of the foliar products resulted in significant differences at either location (Table 1).

Table 1. Foliar Fertilizer Did Not Affect Soybean Yields in 2020.

Product	Nutrient(s) Supplied	Company	Rate	Timing	Princeton	Lexington
					Yield, bu/A*	
FertiRain	N,P,K,S,Mn,Fe,Mn	AgroLiquid	3 gal/A	R3	74	70
SureK	N,P,K	AgroLiquid	3 gal/A	R3	70	74
HarvestMoreUreamate	N,S,B,Mn,Zn	Stoller	2.5 lbs/A	R3	66	76
Smart B-Mo	B,Mo	Brandt	1 pt/A	R3	69	73
Smart Quarto Plus	S,B,Mo,Mn,Zn	Brandt	1 qt/A	R3	69	78
Maximum NPact K	N,K	Nutrien	1.5 gal/A	R3	69	74
Non-Treated Check	Untreated	-	-	-	69	76
				p-value	0.7224	0.2857
					69	74

* All Yields adjusted to 13% moisture.

Single applications of foliar fertilizers have rarely resulted in yield increases in our soybean trials where soil fertility is adequate. Some of the foliar fertilizer labels suggest making multiple applications. There continues to be interest in foliar fertilizers and we expect to continue conducting research.

We thank the Kentucky Soybean Promotion Board for their funding of this effort. We also thank James Dollarhide, Julia Santoro, Dan Quinn and Ryan Murphy at Lexington and Conner Raymond, Hunter Adams, Curtis Bradley and Sloane Boren at Princeton for their assistance.

Testing Sulfur Fertilizer on Soybean Yield and Seed Composition

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Sulfur (S) is an essential element to crop growth and is considered a macronutrient like nitrogen, phosphorus and potassium. Historically, we have not needed to apply nitrogen or sulfur to soybeans for yield improvements when fields have been adequately inoculated with *Bradyrhizobium japonicum*.

Many farmers are interested in using sulfur applications to try to improve soybean yields. Normally, we expect soil organic matter to release sulfur from organic compounds during the growing season. We expect those releases to be sufficient for soybean growth, development and yield. As we strive for higher soybean yields, we were interested if sulfur could improve soybean yields.

We partnered with researchers from Wisconsin, Ohio, Indiana, Minnesota, North Carolina, Arkansas, Louisiana, Virginia and Georgia in developing a uniform treatment protocol. The Kentucky Soybean Board funded the Kentucky portion of the research.

Full season soybeans were planted at Princeton and Lexington. Sulfur was applied at 10, 20 and 30 lb S/acre as either Ammonium Sulfate (AMS) or Calcium Sulfate (CaSO4). Since AMS also supplies nitrogen, we included treatments of 9, 18 and 26 lb N/A to correspond with the three AMS rates. The Urea treatments serve as a check against the AMS treatments.

Table 1. Sulfur and Nitrogen Treatment Effect on 2020 Soybean Yields and Seed Composition.

	Princeton		Lexington		
Treatment	**Yield, bu/A**		**Yield, bu/A**	**Protein, %**	**Oil, %**
Non-Treated Check	68	b	83	40.1	19.8
AMS, 10 lb S/A	75	ab	85	40.0	19.6
AMS, 20 lb S/A	70	b	87	40.2	19.7
AMS, 30 lb S/A	76	ab	85	40.2	19.8
Calcium Sulfate, 10 lb S/A	73	ab	81	40.0	19.7
Calcium Sulfate, 20 lb S/A	73	ab	79	40.3	19.6
Calcium Sulfate, 30 lb S/A	69	b	79	40.0	19.6
Urea, 9 lb N/A	79	a	83	40.4	19.6
Urea, 18 lb N/A	70	b	86	39.7	19.8
Urea, 26 lb N/A	74	ab	82	40.1	19.6
p value	0.0052		0.3527	0.1677	0.7736
Average	73		83	40.1	19.7

Soybean yields at Princeton averaged 73 bushels per acre and Lexington averaged 83 bushels per acre. At Princeton, the highest yield occurred from Urea at 9 lb N/acre (Urea 9). Five other treatments resulted in yields similar to the Urea 9 treatment (AMS, 10 lb S/A; AMS 30 lb/A; CaSO4 10 lb S/A; CaSO4 20 lb/A and Urea 26 lb N/A). However, all five of those treatments were not significantly different from the lowest-yielding treatments. The three lowest yields at Princeton occurred with the Non-treated check, AMS, 20 lb S/A and Urea 18 lb N/A.

At Lexington, the soybean yields were not significantly affected by the sulfur and nitrogen treatments. In addition, protein and oil were not affected by the sulfur and nitrogen treatments. Yields averaged 83 bushels per acre, 40.1 % oil and 19.7% protein.

These results are a bit confusing. There are not consistent yield increases from treatments at Princeton. For example, AMS at 10 and 30 lb S/A were among the highest yields while AMS 20 lb S/A was among the lowest yields. Urea at 9 and 26 lb N/A were among the highest yields while Urea at 18 lb N/A was among the lowest yields.

CONCLUSIONS

While some sulfur and nitrogen treatments increased yields at Princeton, others decreased yields. None of the sulfur and nitrogen treatments affected yields at Lexington, which averaged 13.6% higher yields than Princeton. None of these treatments affected oil and protein as Lexington. These results from Kentucky will be grouped with results from other states and that larger analysis may provide a clearer understanding of sulfur fertilizer effects on soybean yields.

We thank the Kentucky Soybean Promotion Board for their funding of this effort. We also thank James Dollarhide, Julia Santoro, Dan Quinn and Ryan Murphy at Lexington and Conner Raymond, Hunter Adams, Curtis Bradley and Sloane Boren at Princeton for their assistance.

College of Agriculture, Food and Environment

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