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RESEARCH

Value of an Insecticide Added to a Fungicide for Soybean during Drought

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Abstract

Due to pesticide application costs, many farmers will commonly tank mix a low-cost pyrethroid insecticide with a fungicide to save an application cost. Research was conducted at Novelty and Portageville, MO, in 2011 and 2012 to evaluate the impact of an insecticide (lambda-cyhalothrin at 0.025 lb a.i./acre) plus fungicide (pyraclostrobin at 0.098 lb a.i./acre) application at the R3 and R5 stages of soybean [*Glycine max* (L.) Merr.] development compared with insecticide applications made at threshold insect populations. Insect pest populations included 21 different types, while beneficial insects totaled 13 groups over the R3 to R7 insect monitoring period. At both locations, rainfall was below normal and none of the threshold monitored treatments reached insect pest populations that warranted an insecticide application during the 2 years of this research. An insecticide application at R3 decreased pest and beneficial insect populations compared with the nontreated control, while the R5 insecticide application decreased insect pest populations, but had no significant effect on beneficial insects ($P = 0.13$). There was no significant difference ($P = 0.3$) in grain yields for the insecticide and/or fungicide treatments at the four moderate-yielding (38.4–40.2 bu/acre) site-years. Scouting for insect pests was extremely important to avoid unnecessary crop production expenses especially in drought years where crop yields may be lower than normal.

Many farmers make fungicide applications at a wide range of reproductive development stages (R3–R5) (Fehr and Caviness, 1971) of soybean development (Klingelfuss et al., 2001; Dorrance et al., 2010; Bradley and Sweets, 2008; Johnson et al., 2009; Swoboda and Pedersen, 2009; Nelson et al., 2010). Due to pesticide application costs, many farmers will tank mix a low-cost insecticide, such as a pyrethroid, with the fungicide to save an application cost. While the immediate cost of the pyrethroid may be minimal, there may be negative consequences later in the season.

Low-level insect infestations help sustain beneficial insects within the field, but an insecticide applied with a fungicide may eliminate beneficial insects and allow pest populations to

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Abbreviation: SDS, sudden death syndrome.

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Table A. Useful conversions.

To convert Column 1 to Column 2, multiply by	Column 1 Suggested Unit	Column 2 SI Unit
0.304	foot, ft	meter, m
2.54	inch	centimeter, cm (10^{-2} m)
1.609	mile, mi	kilometer, km (10^{-3} m)
0.405	acre	hectare, ha
3.78	gallon, gal	liter, L (10^{-3} m^3)
454	pound, lb	gram, g (10^{-3} kg)

rebound in their absence (Stern et al., 1959; Hardin et al., 1995; Johnson et al., 2009). Insect pests persist in the field at different levels throughout the growing season and may not be present at threshold levels at the time a midseason fungicide application is made. For instance, soybean aphid (*Aphis glycines* Matsumura) can be a late-season pest between R1 and R5 (Beckendorf et al., 2008; Ragsdale et al., 2007; Rhainds et al., 2007). Redbanded stink bugs [*Piezodorus guildinii* (Westwood)] often do not reach economic thresholds until R4 to R7 (Temple et al., 2013), whereas the southern green stink bug [*Nezara viridula* (L.)] reaches peak populations near R6 (Schumann and Todd, 1982). Furthermore, some insects like velvetbean caterpillar (*Anticarsia gemmatalis* Hübner) and Mexican bean beetles (*Epilachna varivestis* Mulsant) usually reach peak populations on soybean based on their biology regardless of crop phenology (McPherson et al., 1996). One of the basic principles of integrated pest management of insects entails knowing which species are present and at what level because natural enemies can keep pest levels low; however, an insecticide applied with a fungicide at R3 when beneficial insects are present with low levels of insect pests could lead to an increase in insect pests (Johnson et al., 2009). This could, in turn, necessitate a second insecticide application because natural enemies are no longer present to prey on pest insects. Additionally, there are concerns that fungicides can have a negative impact on entomopathogenic fungi that help keep some insect pest populations low (Johnson et al., 2009).

Multivoltine insect species tend to build populations as the year progresses, which often leads to pests migrating to a field after an early fungicide application is applied; therefore, when insects move into the field later in the season, the insecticide is no longer present and a second application may be warranted. Pyrethroids typically have a short residual (Nagia et al., 1989; Long et al., 2000; Lorenz et al., 2002; Baur et al., 2003; Zeledón et al., 2003; Akin and Howard, 2012). Lastly, the addition of an insecticide when pests are at subthreshold levels can place unnecessary selection pressure on insects and speed up the development of insecticide resistance (Stern et al., 1959; Phillips et al., 1989). This is of particular concern with corn earworm [*Helicoverpa zea* (Boddie)]. Corn earworm is a migratory insect that utilizes cotton (*Gossypium hirsutum* L.), grain sorghum (*Sorghum bicolor* L.), corn (*Zea mays* L.), and many plants in nonagricultural settings as hosts. This pest is often exposed to pyrethroid insecticides in multiple crops throughout a growing season from south Texas to southern Canada, and it has developed resistance to some pyrethroid insecticides (Martin et al., 2000; Hutchison et al., 2007; Pietrantonio et al., 2007; Jacobson et al., 2009).

Preventive fungicides, such as strobilurins, have sometimes increased yields in soybean (Klingelfuss et al., 2001; Dorrance et al., 2010; Nelson et al., 2010; Nelson and Meinhardt, 2011) in the presence or absence of disease, but others have reported no such yield response (Bradley and Sweets, 2008; Swoboda and Pedersen, 2009). Strobilurin fungicides can be used not only for management of soybean diseases such as Septoria brown spot (*Septoria glycines*), Cercospora leaf spot (*Cercospora kikuchii*), and frogeye leaf spot (*Cercospora sojina*) (BASF, 2009; Cruz et al., 2010; Dorrance et al., 2010), but also plant health (BASF, 2009). Adding an insecticide to a preventative fungicide may reduce application costs required for a separate application, but managing insect resistance is important to maintain the availability of cost-effective insecticides (Stern et al., 1959; Phillips et al., 1989). The objective of this research was to evaluate the impact of an insecticide plus fungicide application at the R3 and R5 stages compared with insecticide applications made at threshold when fungicide applications are made at the R3 and R5 stages.

MATERIALS AND METHODS

Field research was conducted in 2011 and 2012 at the University of Missouri's Greenley Memorial Research Center (40°1′17″ N, 92°11′25″ W) near Novelty, MO, and at the Fisher Delta Research Center near Portageville, MO (36°23′39″ N, 89°36′35″ W). This research was arranged as a randomized complete block design with four replications. Treatments included a fungicide (pyraclostrobin at 0.098 lb a.i./acre, carbamic acid, [2,[[[1-(4-chlorophenyl)-1*H*-pyrazol-3-yl]oxy]methyl]phenyl]methoxy-,methyl ester), insecticide (lambda-cyhalothrin at 0.025 lb a.i./acre, [1a(*S**),3a(*Z*)]-(±)-cyano-(3-phenoxyphenyl) methyl-3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate]), pyraclostrobin plus lambda-cyhalothrin, pyraclostrobin plus lambda-cyhalothrin once insect(s) reached thresholds (Bradley et al., 2011), and a nontreated control. Nonionic surfactant (Franchise, a mixture of alkylpolyoxyethylene ethers and free fatty acids, Loveland Industries Inc., Greeley, CO)

Table 1. Soil test values and soybean management practices at Novelty and Portageville, MO, in 2011 and 2012.

Management practice	Novelty 2011	Novelty 2012	Portageville 2011	Portageville 2012
Soil series†	Putnam	Putnam	Tiptonville	Sharkey
Soil test values				
Soil organic matter (%)	2.1	2.8	1.4	4.4
Cation exchange capacity (meq/100 g)	16.4	12.3	11.9	21.1
pH (0.01 M $CaCl_2$)	6.2	6.3	5.7	6.1
Bray I P (lb/acre)	47	25	76	89
Exchangeable (1 M NH_4AOc)				
K (lb/acre)	320	190	375	524
Ca (lb/acre)	4930	3750	3750	6790
Mg (lb/acre)	400	280	240	840
Plot size (ft)	20 by 60	20 by 60	25 by 100	20 by 40
Replications	4	4	4	4
Planting date	2 May	11 Apr.	1 June	25 Apr.
Cultivar	Asgrow 3803	Asgrow 3803	Olympus 1051	P94Y70
Row spacing (inches)	15	15	38	30
Seeding rate (no./acre)	170,000	180,000	130,000	140,000
Tillage	No-till	No-till	Conventional	Conventional
Insecticide application date				
R3 (Fehr and Caviness, 1971)	21 July	3 July	16 Aug.	9 Aug.
Time (h)	0830	1730	1400	0930
Air temperature (°F)	87	100	84	82
Soil temperature (°F)	81	96	104	83
Relative humidity (%)	33	39	46	61
Wind speed (mi/h)	4.4	5	3	7
Wind direction	South	South	East	Southwest
R5 (Fehr and Caviness, 1971)	11 Aug.	24 July	7 Sept.	4 Sept.
Time (h)	1500	1030	0800	1015
Air temperature (°F)	80	100	58	80
Soil temperature (°F)	80	90	61	76
Relative humidity (%)	41	40	82	69
Wind speed (mi/h)	1	1.5	8	8
Wind direction	Northeast	West	Northwest	Southwest
Harvest date	3 Oct.	4 Oct.	24 Oct.	4 Oct.

† Soil series: Putnam silt loam (fine, smectitic, mesic, Vertic Albaqualf), Tiptonville silt loam (fine-silty, mixed, superactive, thermic Oxyaquic Argiudoll), and Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquert).

was added to all treatments that included pyraclostrobin. Fungicide and/or insecticide treatments were applied at R3 and R5 stages of soybean development (Fehr and Caviness, 1971). A CO_2-propelled hand-boom equipped with eight 8002 flat-fan nozzles (Spray Systems Co., Wheaton, IL) spaced 15 inches apart was calibrated to deliver 15 gal/acre at 16 lb/sq inch while traveling at 2.9 mi/h to apply insecticide and/or fungicide treatments. Environmental conditions and soybean development at the time of application are listed in Table 1. Plots were monitored with a sweep net before insecticide applications to identify insects present. Most insects were identified to family (Johnson and Triplehorn, 2004) but common agricultural pests were identified to species; however, for the purpose of analysis insects were grouped in categories of insect pests, beneficial insects, and other insects (i.e., insects that are considered as neither pests or beneficial). Thrips were counted; however, they were so numerous across all treatments, they were excluded from the analysis. If thresholds were never reached, this treatment was a fungicide-only treatment. The threshold management plots were monitored weekly beginning at R3 for the remainder of the season until R7 (physiological maturity) and were treated as needed.

The site soil characteristics were determined from analysis of soil samples (0–6 inches deep) by the University of Missouri Soil and Plant Testing Lab (Buchholz, 1992) along with soybean management information are reported in Table 1. All plots were maintained weed-free with appropriate preemergence followed by postemergence herbicide applications made to the entire plot area based on local practices. Plant populations before harvest were determined at Novelty but not at Portageville. The severity of diseased plants in each plot was assessed based on a percentage of the canopy (0–100%) with symptoms of Septoria brown spot, frogeye leaf spot, sudden death syndrome (SDS) [*Fusarium solani* (Mart.) Sacc. f.sp. *glycines*], or soybean rust (*Phakopsora pachyrhizi*) at the beginning of the R6 stage of development. These trials were also designed to assess the potential impact of these treatments on soybean rust, but none developed at either location. Septoria brown spot and

Table 2. Number of insect pests, beneficial insects, and other insects at R3, 1 week after R3 (R3 + 1 wk), R5, and 1 week after R5 (R5 + 1 wk). Data were combined over sites (Novelty and Portageville, MO) and years (2011 and 2012).

Pesticide treatment	R3			R3 + 1 wk			R5			R5 + 1 wk		
	Pests†	Beneficial	Other	Pests	Beneficial	Other	Pests	Beneficial	Other	Pests	Beneficial	Other
	no./20 sweeps											
Nontreated	1.8	3.6	3.8	3.1	4.3	9.1	1.3	1.1	1.4	2.8	2.6	4.9
Fungicide‡	2.2	4.6	4.7	–§	–	–	2.4	1.2	1.6	–	–	–
Insecticide¶	2.9	4.0	4.8	1.8	3.0	10.0	2.0	0.8	1.5	1.1	1.4	3.9
Fungicide + insecticide	2.9	3.0	4.7	1.9	2.8	9.3	1.9	1.4	1.5	1.0	1.9	4.5
LSD ($P \leq 0.1$)	NS#	NS	NS	0.7	1.2	NS	NS	NS	NS	0.7	NS	NS
$P > F$	0.83	0.38	0.89	0.01	0.09	0.98	0.29	0.40	0.98	0.0002	0.13	0.60

† Pest insects from R3 to R7 (Fehr and Caviness, 1971) included *Hemiptera:* three-cornered alfalfa hopper (Membracidae: *Spissistilus festinus*), stinkbug (Pentatomidae), potato leafhopper (Cicadellidae*: Empoasca fabae*), whiteflies (Aleyrodidae), aphids (Aphididae), garden fleahopper (Miridae: *Halticus bractatus*); *Orthoptera:* grasshoppers (Acrididae and Tettigoniidae); *Coleoptera:* bean leaf beetle (Chrysomelidae: *Cerotoma trifurcata*), flea beetle (Chrysomelidae), spotted cucumber beetle (Chrysomelidae: *Diabrotica undecimpunctata*), clover stem borer (Languriidae: *Languria mozardi*), weevil species (Curculionidae), leaf beetles species (Chrysomelidae), dectes stem borer (Cerambycidae: *Dectes texanus*); *Lepidoptera:* green cloverworm (Erebidae: *Hypena scabra*), corn earworm (Noctuidae: *Helicoverpa zea*), woolybear caterpillar (Erebidae: Arctiinae), pierid caterpillars (Pieridae), soybean looper (Noctuidae: *Chrysodeixis includens*); *Thysanoptera:* thrips; and mites (Arachnida: Acari). Thrips were not included in the total pest number, but were quantified (data not presented). Beneficial insects included *Neuroptera:* lacewings (Chrysopidae); *Coleoptera:* lady beetles (Coccinellidae), red cross beetle (Melyridae: *Collops* sp.), ground beetles (Carabidae), checkered beetles (Cleridae); *Hemiptera:* big eyed bug (Geocoridae), minute pirate bug (Anthocoridae), spined soldier bug (Pentatomidae: *Podisus maculiventris*), damsel bug (Nabidae), assassin bug (Hemiptera: Reduviidae); *Hymenoptera:* parasitic wasps, bees (Apidae); and spiders (Arachnida: Araneae). Other insects included *Hemiptera:* leafhoppers (Cicadellidae), plant bugs (Miridae sp., including *Lygus lineolaris*), seed bugs (Lygaeidae), scentless plant bugs (Rhopalidae); *Diptera:* flies; *Lepidoptera:* geometrid caterpillars (Geometridae), blue butterflies (Lycaenidae); *Collembola:* springtails; *Coleoptera:* ant-like flower beetles (Anthicidae); and *Hymenoptera:* ants (Formicidae).

‡ Fungicide was pyraclostrobin at 0.098 lb a.i./acre plus nonionic surfactant at 0.25% v/v.

§ Data were not collected.

¶ Insecticide was lambda-cyhalothrin at 0.025 lb a.i./acre.

NS, not significant.

frogeye leaf spot were rated as the percentage of leaf area with lesions over the entire canopy and defoliation of each plot. The severity of SDS was rated before leaf drop as previously described (Howard et al., 1999). Yield data were collected using a small-plot combine (Wintersteiger Delta, Salt Lake City, UT, at Novelty and Massey 8, Kincaid Equipment Manufacturing, Haven, KS, at Portageville) and yields were adjusted to 13% moisture before analysis.

Data were subjected to ANOVA using the SAS v9.4 statistical program (SAS Institute, 2014) to determine if there were significant treatment effects. Data were pooled over years in the absence of significant two-way interactions (site-year × treatment). Fisher's Protected LSD ($P = 0.05$) was used to separate significant differences among means.

RESULTS AND DISCUSSION

Weather conditions during this research were considered abnormally dry in 2011 and an extreme drought in 2012 (USDM, 2015). During the summer of 2012, temperatures were abnormally high. In 2011, rainfall was low during pod fill (September), while in 2012 it was low throughout July and August (data not presented). Environmental conditions at the time of application are listed in Table 1.

Most preventative fungicides in this region are applied at R3 (Nelson et al., 2010; Nelson and Meinhardt, 2011), while insecticides should only be applied when insect pests are present at threshold levels and if an insecticide is tank mixed with the fungicide at the R3 application. Often insect pests are not present at threshold levels during an early fungicide application. Pesticide applications at Novelty had no effect ($P = 0.62$) on soybean plant density at harvest (data not presented). Due to relatively dry growing conditions through the summer months of 2011 and 2012 (Nash et al., 2015), development of foliar diseases at Novelty (severity of Septoria brown spot was <3% and frogeye leaf spot was <2%) or SDS, soybean rust, Septoria brown spot, and frogeye leaf spot at Portageville was limited (severity was <1%) (data not presented), while insect pest populations were generally low (Table 2).

Insect pests included 21 different species/types, while beneficial insects totaled 13 different species/types over the period of monitoring (R3 until R7, physiological maturity). At R3, there were 1.8 to 2.9 insect pests/20 sweeps while there were 3 to 4.6 beneficial insects/20 sweeps (Table 2). An insecticide application at R3 decreased pest and beneficial insect populations 1.3 to 1.5/20 sweeps compared with the nontreated control, but had no significant effect on other insects. Insect pest populations remained at 1.3 to 2.4/20 sweeps at R5, but beneficial insect populations were 0.8 to 1.2/20 sweeps. The R5 insecticide application decreased insect pest populations 1.7 to 1.8/20 sweeps compared with the nontreated control; however, there was no significant effect of the insecticide application on beneficial or other insects compared with the nontreated control. This indicated

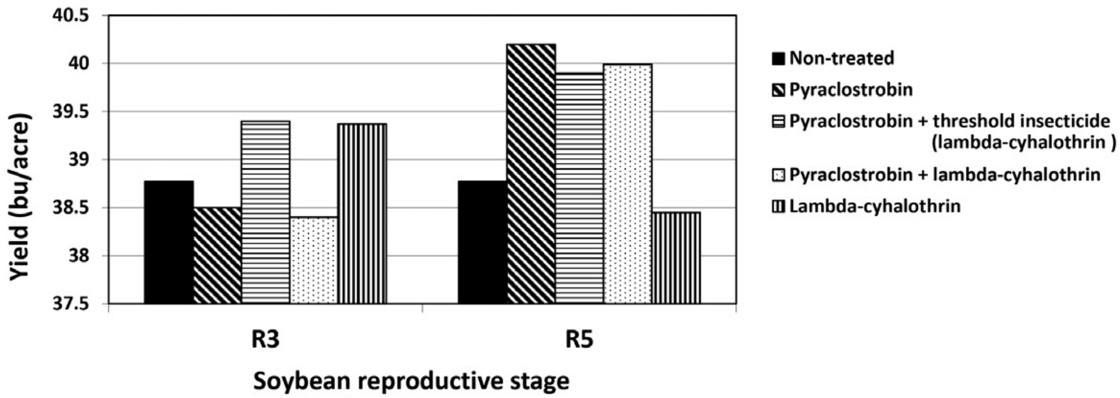

Fig. 1. Soybean yield response to an insecticide added to a strobilurin fungicide application at R3 and R5 (Fehr and Caviness, 1971). Data were combined over site-years (Novelty and Portageville, MO, in 2011 and 2012). There was no significant difference between for pesticide applications applied at the two soybean stages of development (*P* = 0.30).

that delaying insecticide applications until R5 would have less of an impact on beneficial insect populations during extreme and severe droughty conditions (USDM, 2015).

Grain yields averaged <40 bu/acre (Fig. 1) and no significant differences (*P* = 0.30) between pesticide treatments were detected. Preventive fungicides, such as strobilurins, have sometimes increased yields in small grains (Grossmann and Retzlaff, 1997; Grossmann et al., 1999; Bayles and Hilton, 2000) and soybean (Klingelfuss et al., 2001; Dorrance et al., 2010) in the absence of disease due to a physiological effect of the fungicides on plants (Köehle et al., 2002; Venancio et al., 2003); however, we observed no difference in yield during the dry conditions experienced in 2011 and 2012. There was no economic benefit of adding an insecticide at R3 or R5 (data not presented). In other research at Novelty, significant increases (up to 11 bu/acre) in yield with strobilurin fungicides have been observed in higher yielding environments (>55 bu/acre) when the severity of Septoria brown spot and frogeye leaf spot was greater, and with pyrethroid insecticides when threshold levels of soybean aphids were observed (Nelson et al., 2010). Similarly, there was a 5.5 bu/acre increase in grain yields in plots treated with pyraclostrobin in a higher yielding (>60 bu/acre) environment at Columbia, MO, which is between Novelty and Portageville, compared with low-yielding sites where no yield increase was observed (Bradley and Sweets, 2008). However, another study conducted in a low-insect-pressure environment found a 5% increase in seed number with an insecticide application at R4 (Henry et al., 2011). Although insect counts were not collected, the authors speculated the increase in seed number was the result of an unknown seed predator being removed by the insecticide. None of the threshold monitored plots reached insect populations that warranted an insecticide application; therefore, scouting for insect pests was particularly important to avoid unnecessary crop production expenses especially when the yield potential is in the medium (40 bu/acre) to low range. In a similar study where tank mixes of fungicide and insecticide were applied prophylactically or when needed based on integrated pest management strategies and scouting, the authors found there was a benefit to an insecticide application when used as indicated by scouting and that there was an economic benefit of scouting compared with a prophylactic insecticide application at the time of a fungicide application (Johnson et al., 2009).

CONCLUSIONS

There was no effect of insecticide or fungicide treatments on soybean seed yield during the 2 years of this research with below-normal rainfall. Farmers and crop consultants should monitor insect pests and treat at threshold levels to maintain good integrated pest management strategies. Otherwise, unnecessary crop production expenses are incurred as well as the detrimental effects of preventative applications on beneficial insect pests.

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