Research

Quantifying the Effects of Fungicides and Tillage on *Cercospora sojina* Severity and Yield of Soybean

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Abstract

A field study was conducted in 2014 through 2016 at the University of Tennessee Research and Education Center, Milan, TN, to determine fungicide effects on frogeye leaf spot (FLS) caused by *Cercospora sojina* and to determine disease severity and yield under no-till and tillage. Each plot was visually rated for FLS severity based on the percent leaf area covered from 0 to 100%. The result showed that tillage did not affect severity of the disease or yield. However, there were significant effects from fungicide, year-to-year effects, and fungicide × year interactions. Among the three years, disease severity in 2016 was greater than in 2014 and 2015. Among the six fungicides, Topsin, Topguard, Quadris TOP SBX, and Priaxor significantly ($P \leq 0.05$) reduced maximum disease severity in 2016. All fungicide applications improved yield relative to the untreated check. Topsin and Quadris TOP SBX, however, had consistently the highest percent yield increases. These results suggest that not all fungicides that reduced FLS severity equally protected yield, indicating that yield and environmental conditions need to be considered when making appropriate fungicide recommendations in tilled and no-till systems.

Frogeye leaf spot (FLS) of soybean, caused by the necrotrophic fungus *Cercospora sojina* K. Hara, is a serious disease of soybean (*Glycine max* [L.] Merr.) worldwide. It is primarily a foliar disease, even though seeds, pods, and stems can also be affected (Grau et al. 2004; Wise and Newman 2015). In the southern United States, FLS has caused severe problems for many years but has also been reported to affect yield in the northern United States (Phillips 1999; Yang et al. 2001). Yield loss from FLS is mainly owing to reduced photosynthetic area and premature defoliation, resulting in reductions of yield of 10 to 60% (Akem and Dashiell 1994). Mian et al. (1999) compared the performance of four pairs of FLS-susceptible versus FLS-resistant near-isogenic lines (NILs) and determined that yield losses for the four susceptible soybean cultivars were as high as 31% compared with the respective resistant NILs. In northern U.S. locations, FLS severity and yield loss may be attributed to warmer winter temperatures, susceptible soybean germplasm, and no-till practices (Cruz and Dorrance 2009; Dorrance et al. 2010; Mengistu et al. 2002; Wrather and Koenning 2006; Yang et al. 2001). The intensity of FLS increases in regions with warm and humid environmental conditions because the pathogen requires prolonged moisture for adequate infection of new leaves (Wise and Newman 2015).

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The historical practice of burying plant residues by tillage has been promoted to reduce the soil-borne and/or debris-borne plant pathogens (Boosalis et al. 1981). Because *C. sojina* survives in residue, cultural practices such as tillage were aimed at reducing inoculum-borne residues and assisting in the control of FLS. However, in the last two decades, in the southern United States, the largest shift in agricultural production has been from conventional tillage to no-till systems, in which soybean is frequently in rotation with corn and cotton (Bockus and Shroyer 1998). Widespread adoption of conservation tillage combined with continuous corn and high levels of surface residue, however, are believed to be responsible for the prevalence and severity of gray leaf spot throughout the Corn Belt (Latterrel and Rossi 1983; Nutter et al. 1993), and similar practices with no-till systems combined with continuous soybean are believed to be responsible for the prevalence and severity of FLS in the United States (Mengistu et al. 2014). Research results in no-till experiments show that yield was greater and FLS severity was reduced when fungicides were applied at growth stages R3 and R5 for FLS management (Mengistu et al. 2014; Swoboda and Pedersen 2009). Nevertheless, fungicides have become a significant part of soybean disease management programs in the northern and southern United States when disease-resistant soybean is not planted or is unavailable, and also when soybean producers have been applying fungicides to control FLS and late-season diseases under no-till cropping system. The use of quinone outside inhibitor (QoI) or strobilurin fungicides for soybeans has been a necessary tool in plant disease management programs because of the broad spectrum activity against many phytopathogens when susceptible cultivars are planted (Sauter et al. 1999; Vincelli 2002). Unfortunately, resistance to QoI fungicides in isolates of *C. sojina* was first detected in 2010 from a west Tennessee soybean field where repeated fungicide applications failed to manage FLS (Zhang et al. 2012b). Since its first detection, soybean fields in the southern and midwestern United States (Alabama, Arkansas, Illinois, Indiana, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Ohio, Tennessee, and Virginia) have confirmed resistance to QoI chemistry (Standish et al. 2015; Zhang 2012; Zhang et al. 2012a, b). Race-specific resistance to *C. sojina* in soybean, conferred by the *Rcs3* gene (Mian et al. 1999), imposes intense selective pressure on the pathogen population, and the risk of severe disease epidemics has become imminent. The QoI group of fungicides is classified as high risk by the Fungicide Resistance Action Committee owing to their single-site mode of action (FRAC 2018).

Products labeled for management of FLS of soybean include active ingredients that fall into five fungicide groups determined by the Fungicide Resistance Action Committee (FRAC 2018), which are as follows: (i) demethylation inhibitors (DMIs), which include cyproconazole, difenoconazole, flutriafol, propiconazole, prothioconazole, tebuconazole, and tetraconazole; (ii) methyl benzimidazol carbamate (MBC), which includes thiophanate methyl; (iii) succinate dehydrogenase inhibitors (some of which will be labeled for soybean in 2018), which include benzovindiflupyr, boscalid, fluxapyroxad, and penthiopyrad; (iv) QoIs, which include azoxystrobin, fluoxastrobin, picoxystrobin, pyraclostrobin, and trifloxystrobin; and (v) chloronitriles, which include chlorothalonil. Many fungicide products contain multiple active ingredients from multiple fungicide groups; for example, Quadris TOP SBX contains difenoconazole (DMI) and azoxystrobin (QoI). Several QoI fungicides, notably azoxystrobin and pyraclostrobin, are commercially available for use on soybeans in the United States (Sauter et al. 1999) and had become a major tool in FLS management when susceptible cultivars were planted. However, recent fungicide efficacy studies on other diseases (for example, for the control of Sclerotinia blight in the north central region of the United States) indicate inconsistent results from the use of such fungicides depending on the active ingredient of the fungicide applied as well as the application timing (Huzar-Novakowiski et al. 2017). As one disease-management tool to control FLS, the use of fungicides with different modes of action and/or combination with cultural practices may be needed to reduce disease severity and protect yield. Studies conducted on a combination of fungicides for controlling FLS caused by QoI fungicide-resistant *C. sojina* indicate that fungicides in the triazole (DMI) and benzimidazole (MBC) groups are effective (Zhang 2012). Studies that combine several fungicide chemistries under no-till and till practices on FLS epidemics and yield, however, are not available. The use of fungicides with different chemistry classes to reduce the selection pressure on the fungal population could prolong the efficacy of fungicide applications in production areas under tilled and no-till cultivation. The objective of this study was to measure FLS severity and soybean yield under tilled and no-till cultivation with and without applications of six different fungicides at R3 and R5 stages of soybean growth.

Experimental Field Plots and Treatments

A field study was conducted from 2014 through 2016 at the Research and Education Center, University of Tennessee, Milan, TN. The soil was a Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapludalfs). Weed management systems were designed for effective weed control using pre- and postemergence herbicide applications in all plots. Soybean was planted at a rate of 24 seeds/m using an Almaco plot planter equipped with John Deere XP row units. Soybean was irrigated using a center pivot irrigation system distributing approximately 1.0 cm of water per irrigation event.

This experimental design and test site were similar to a previously published study (Mengistu et al. 2014), which was a randomized complete block with a split-plot type arrangement with tillage (till and no-till) as the main plots. Fungicide treatments were used as subplot with four replications. A susceptible cultivar ('Asgrow 4832') was planted in each plot. Each subplot consisted of four rows spaced 76.2 cm apart and 6 m long. Two rows of the FLS-resistant cultivar ('Asgrow 4632') were planted between plots to minimize border effect and reduce disease pressure across the research area. The untreated plot served as a control to generate data on baseline disease severity and yield levels each year. The field was divided into six blocks. Half of each block was tilled and the other half was no-till. The tilled plots were prepared using a 1.82-m-wide King Kutter gear-driven tiller model TG-72-Y (King Kutter, Winfield, AL) to cut to a depth of approximately 12 cm in the initial pass. A secondary pass was made to provide efficient soil crushing and mixing. This resulted in a final tillage depth of approximately 24 cm. The tillage passes were followed immediately by a Case IH roller harrow to conserve soil moisture and to firm up the soil seed bed prior to planting. No-till plots received no preplanting operations, and the desiccated winter weed residues were left undisturbed. Alleys separating the blocks were 1.5 m in length. This research area has been utilized for tilled and no-till cultivation research for the past 7 years, and the same tillage blocks have been maintained.

The recommended dose of six different fungicides encompassing the five fungicide groups labeled for FLS was applied at the R3 (beginning pod) and R5 (beginning seed) growth stages (Fehr et al. 1971). The product name, rate of application, active ingredient, fungicide group name, and Fungicide Resistance Action Committee (FRAC 2018) code are shown in Table 1.

Fungicide applications were made using a Spider sprayer equipped with a broadcast spray boom with nozzles set on 50.8-cm centers and fixed to accommodate four 76.2-cm rows. The sprayer was calibrated for output of 187 liters/ha using TeeJet XRC 11002 extended-range flat fan spray tips at a speed of 4.8 km/h with spray pressure regulated to 358.5 kPa. The commercial formulation of each fungicide was used with a surfactant (Induce, Helena, Memphis, TN) at a rate of 915 ml/ha.

Soybean yield was determined from the two center rows of each subsubplot at plant maturity. To determine yield, the center two rows of each plot were harvested using a Massey Ferguson 8 XP plot combine equipped with a conventional header with sickle bar cutting knife. Seed weight and grain moisture were collected by weigh buckets and a blade-type moisture sensor with a Juniper Systems Harvest Master program (Juniper Systems, Logan, UT). Harvested seed weight was adjusted to 13% moisture content to determine yield. Percent yield protected was calculated as [(treated – untreated)/treated] × 100.

FLS Severity Rating

Disease severity was recorded every week from the initial appearance of FLS to the last rating period. The corresponding growth stages and days after planting for each rating period are reported in Table 2. Each plot was visually rated for FLS severity based on the percent leaf area covered, from 0 to 100% (Fig. 1). Prior to each rating period, the software (SoybeanPro version 3.4 developed by Forrest W. Nutter, Jr.) that generates digital images of severity levels for FLS was used to calibrate the raters in visual disease assessment. Raters' estimates of severity levels are compared with actual severity levels on digital images, and prior to taking ratings in the field a rater had to achieve 95% or better accuracy. The maximum FLS severity was used to calculate disease control as [(untreated – treated)/untreated] × 100. The average minimum and maximum air temperatures, daily precipitation, and daily irrigation amount were recorded at the Research and Education Center in Milan, TN (Fig. 2).

Statistical Analysis

Analysis of variance (ANOVA) was performed for each year using a general linear mixed model with PROC MIXED in SAS version 9.3 (SAS Institute, Cary, NC). The ANOVA contained fixed effect for tillage as main effect and fungicide as subplot treatment. Random effects were block and block × tillage. To test tillage and fungicide effects on FLS severity over the three years, least squares means were obtained from ANOVA for disease severity recorded for each rating and yield data for each year. Pairwise mean comparisons were made between various treatment combinations based on the significance of the F test and the least squares mean values.

Effectiveness of Fungicides on FLS Severity and Yield

Weather conditions during the cropping seasons in 2014 through 2016 were variable (Fig. 2), having varied effects on the severity level of FLS each year. Total precipitation for July and August of 2016 was greater than in 2014 and 2015. The number of days with the maximum air temperature exceeding 35°C was greater for June, July, and August (16 days) in 2016 than in 2014 (2 days) or 2015 (11 days) (Fig. 2). There was a spike in rainfall amount of 156 mm in August 2016 compared with 110 and 56 mm in 2014 and 2015, respectively.

Analysis of variance indicated that there was no tillage effect on maximum FLS severity (MFS), but there was a significant effect owing to fungicide ($F = 23.78$, $P < 0.0001$), year ($F = 227.8$, $P < 0.0001$), and a significant interaction owing to fungicide × year ($F = 6.04$, $P < 0.0001$) (Table 3). ANOVA also showed that that there was no significant effect of tillage on yield (Table 3), but there were significant fungicide ($F = 5.23$, $P < 0.0006$), year ($F = 8.31$, $P < 0.0187$), tillage × year ($F = 4.76$, $P = 0.0112$), and fungicide × year ($F = 2.34$, $P = 0.0129$) effects.

The least squares mean comparisons between fungicide treatments and untreated checks indicated that a higher and detectable level of disease severity differences occurred beginning at the early R6 stage in 2014, and the early R5 stage in 2015 and 2016, and continued until MFS was reached (Fig. 3). The MFS in 2016 was greater than the MFS in 2014 and 2015, and the untreated checks had significantly greater MFS than all the fungicide treatments except for Headline SC in 2015 (Fig. 3). Both Headline SC and Bravo had poor FLS control every year, compared with other treatments. Quadris TOP SBX, Topsin, and Topguard had the best

TABLE 2
The number of days after planting (DAP) and the growth stages that correspond to rating times each year in a field study at Milan, TN, 2014 to 2016

	2014		2015		2016	
Ratings	DAP	Growth stage	DAP	Growth stage	DAP	Growth stage
1	64	R2	48	R2	68	R3[z]
2	71	R3[z]	55	R3[z]	75	R3
3	78	R3	62	R4	82	R3
4	85	R4	71	R5[z]	89	R4
5	92	R4	76	R5	96	R5[z]
6	99	R5[z]	83	R5	104	R5
7	106	R5	91	R6	110	R6
8	113	R6	97	R6	117	R6
9	120	R6	104	R6	126	R6
10	127	R6	…	…	…	…

[z] Time period when fungicides were applied: R3 refers to beginning pod, when pod is 1/3 inch long at one of the four uppermost nodes on the main stem with a fully developed leaf, and R5 refers to the beginning of seed, when seed is 1/8 inch long in the pod at one of the four uppermost nodes on the main stem with a fully developed leaf. Rating was done every week after the initial frogeye leaf spot appearance.

TABLE 1
Fungicide products used in the field experiment for management of frogeye leaf spot of soybean, applied at R3 and R5[x] growth stages in tilled and no-till main plots located at Milan, TN, 2014 to 2016

Product name	Company name, location	Full label rate	Active ingredient (a.i.)	Rate (kg of a.i./ha)	Rate (g of a.i./ml)	Group name	FRAC code[y]
Bravo Weather Stik	Syngenta Crop Protection, Greensboro, NC	438.27 ml/ha	Chlorothalonil	0.32	0.73	Chlorothalonil (phthalonitriles)	M5
Headline SC	BASF, Research Triangle Park, NC	438.27 ml/ha	Pyraclostrobin	0.11	0.25	Quinone outside inhibitor (QoI/strobilurin)	11
Priaxor Xemium	BASF, Research Triangle Park, NC	292.17 ml/ha	Fluxapyroxad	0.05	0.17	Succinate dehydrogenase inhibitor	7 + 11
			Pyraclostrobin	0.10	0.34	QoI/strobilurin	
Quadris TOP SBX	Syngenta Crop Protection, Greensboro, NC	584.35 ml/ha	Difenoconazole	0.10	0.23	Demethylation inhibitor (DMI/triazole)	3 + 11
			Azoxystrobin	0.12	0.23	QoI/strobilurin	
Topsin 4.5FL	UPI, King of Prussia, PA	1,461 ml/ha	Thiophanate-methyl	0.07	0.55	MBC thiophanates[z]	1
Topguard	FMC Corp., Philadelphia, PA	511.29 ml/ha	Flutriafol	0.06	0.13	DMI/triazole	3

[x] Growth stage refers to the period when fungicides were applied: R3 refers to beginning pod, when pod is 1/3 inch long at one of the four uppermost nodes on the main stem with a fully developed leaf, and R5 refers to the beginning of seed, when seed is 1/8 inch long in the pod at one of the four uppermost nodes on the main stem with a fully developed leaf.

[y] FRAC codes are designated by the Fungicide Resistance Action Committee (http://www.frac.info/, FRAC 2018) as a means of identifying active ingredients with the potential for cross resistance).

[z] MBC = methyl benzimidazol carbamate.

disease control, and Priaxor provided moderate control with MFS lower than untreated checks but greater than the three best treatments previously mentioned (Fig. 3; Table 4). Even when disease severity was lower in 2014 and 2015, Quadris TOP SBX, Topsin, and Topguard still significantly reduced MFS and provided greater disease control compared with the untreated check and other treatments. Average disease control across fungicide treatments was greatest in 2014 with 73%, and 48% in both 2015 and 2016 (Table 4).

Fungicides protected yield in all years based on the percent increased yield above untreated checks. Fungicide applications protected 9 to 16, 6 to 16, and 4 to 20% yield in 2014, 2015, and 2016, respectively. In 2016, Topsin significantly protected the most yield at 20%, whereas Quadris TOP SBX and Priaxor had lower yield protected, 18 and 17%, respectively (Fig. 4). Similar to disease control observations, Headline SC and Bravo provided the lowest yield protection in 2016. In 2015, Quadris TOP SBX and Topsin significantly protected the most yield at 15 and 16%, respectively. Priaxor and Headline SC provided the lowest yield protection in 2015. In 2014, Bravo had significantly lower yield protection than all other treatments. There is a general trend in two of the three years in which the MFS in tillage environments was lower than in no-till even though it was not significant (Fig. 5A). On the contrary, even though there was a significant tillage × year interaction for yield, yield in neither tilled nor no-till was consistently and significantly high across years (Fig. 5B).

This research was conducted to compare the effects of six different fungicide products on tilled and no-tilled plots to suppress FLS on a susceptible cultivar. The combined moisture from

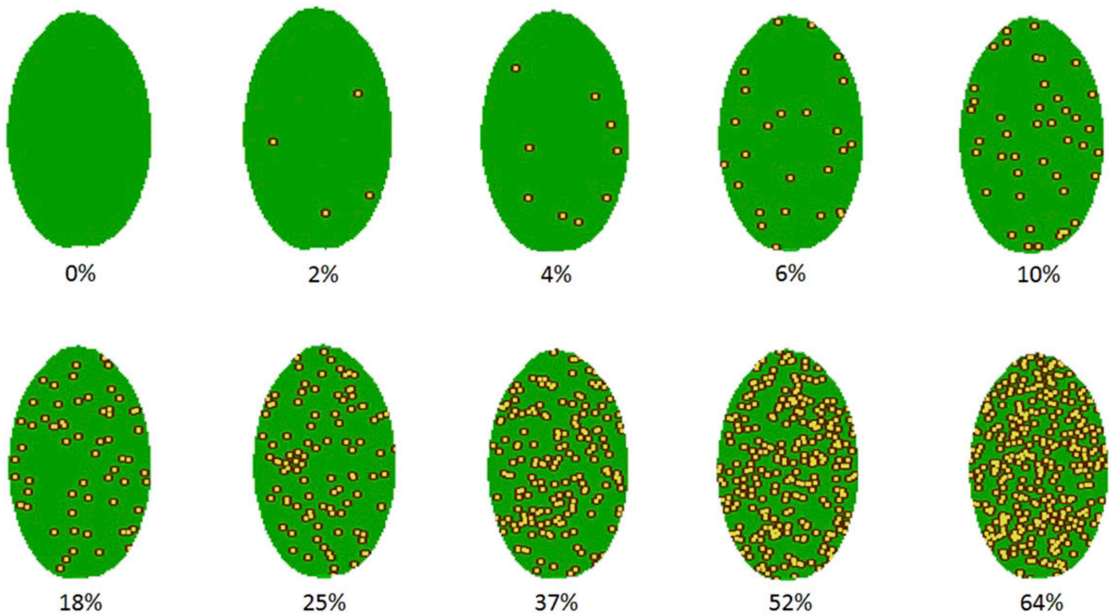

FIGURE 1

Frogeye leaf spot severity ratings based on the percent leaf area covered from 0 to 100%.

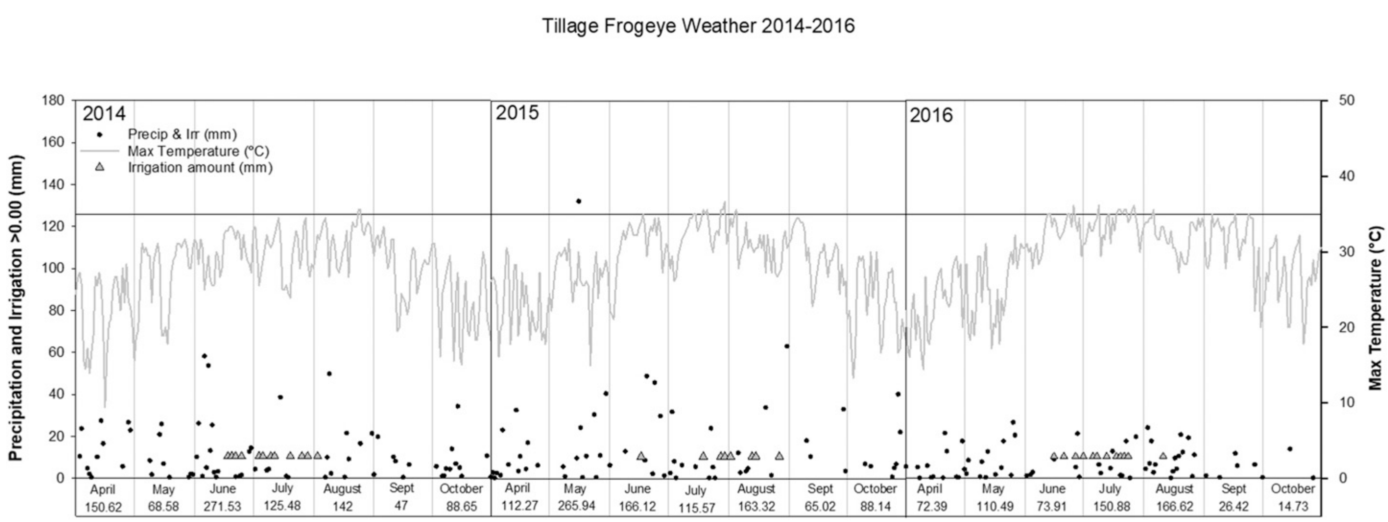

FIGURE 2

Combined irrigation and total precipitation and maximum air temperatures for the months of April through October for 2014 to 2016 at Milan, TN. The line across the graph indicates 35°C, to help visualize the number of days above that temperature.

irrigation and precipitation along with high temperatures in June, July, and August provided conducive conditions for FLS, particularly in 2016. Disease severity in 2016 was greater than disease severity in 2014 and 2015, and this could be owing to the greater precipitation and warmer days in 2016 that provided the most conducive conditions for disease development.

MFS across the 3-year period under no-till showed an increase over the till plots in 2016, when disease severity was high, even though the overall tillage effect was not significant (Table 3; Fig. 5A). Similarly, disease severity was greater in the absence of fungicide application in no-till compared with till, but not significant (data not presented). The trend of greater disease severity in no-till, especially in the absence of fungicide, is similar to what was previously reported (Mengistu et al. 2014). Pathogens that remain alive in soybean debris constitute the source of primary inoculum in the field (Kmetz et al. 1979). According to Baird et al. (1997), soybean debris from a no-till area harbors numerous pathogenic fungi that could increase soybean diseases in the following season, thus reducing yields. Unfortunately, the surface debris may have been washed off during this test more than during the prior testing period Mengistu et al. (2014). The relatively low yields of the untreated checks across years indicate that the yield gains were directly related to disease control by fungicide application. Overall, fungicide application reduced disease severity by 9 to 19% in 2014, 3 to 17% in 2015, and 8 to 34% in 2016, similar to the yield protection of 9 to 16, 6 to 16, and 4 to 20% in 2014, 2015, and 2016, respectively (Figs. 3 and 4). The range of disease reduction and yield protection indicates the effect of year and fungicide in the trial, although disease control was more consistent across years of individual treatments. Treatments in 2015 had the most separation regarding disease control, and treatments in 2016 had the most separation in yield protection. The high level of disease pressure, as indicated by the 45% MFS of the untreated check in 2016, most likely contributed to the greater separation in yield. Although similar trends across the treatments within each year were observed, the difference in the level of percent disease control in 2014 compared with 2015 and 2016 could be attributed to the later disease development at R6 compared with R5 in the later years (Table 3; Fig. 3).

Our results showed that with an equal number of fungicide applications, Bravo and Headline SC fungicides provided poor disease control and yield protection. This can be expected with the fungicide resistance in the FLS pathogen population to the QoI

TABLE 3
Probability of greater values of *F* resulting from type III tests of fixed effects for the maximum disease severity rating (MFS) and yield obtained from SAS PROC MIXED analysis[z]

	MFS		Yield	
Effect	***P* > *F***	***F* value**	***P* > *F***	***F* value**
Tillage (T)	0.0917	6.00	0.7849	0.09
Fungicide (F)	<0.0001*	23.78	0.0006*	5.23
T × F	0.1133	1.87	0.6429	0.71
Year (Y)	<0.0001*	227.76	0.0187*	8.31
T × Y	0.0759	2.66	0.0112*	4.76
F × Y	<0.0001*	6.04	0.0129*	2.34
T × F × Y	0.2452	1.28	0.4275	1.03

[z] The MIXED procedure of SAS was performed, for which the fixed effects are the main effects, and all interactions of tillage, fungicide, and year. The random effects, each nested in tillage, are block (rep), rep × tillage, rep × fungicide, rep × tillage × fungicide, rep × year/rep × tillage × year/rep × tillage. Asterisk (*) indicates significant effect ($P \leq 0.05$).

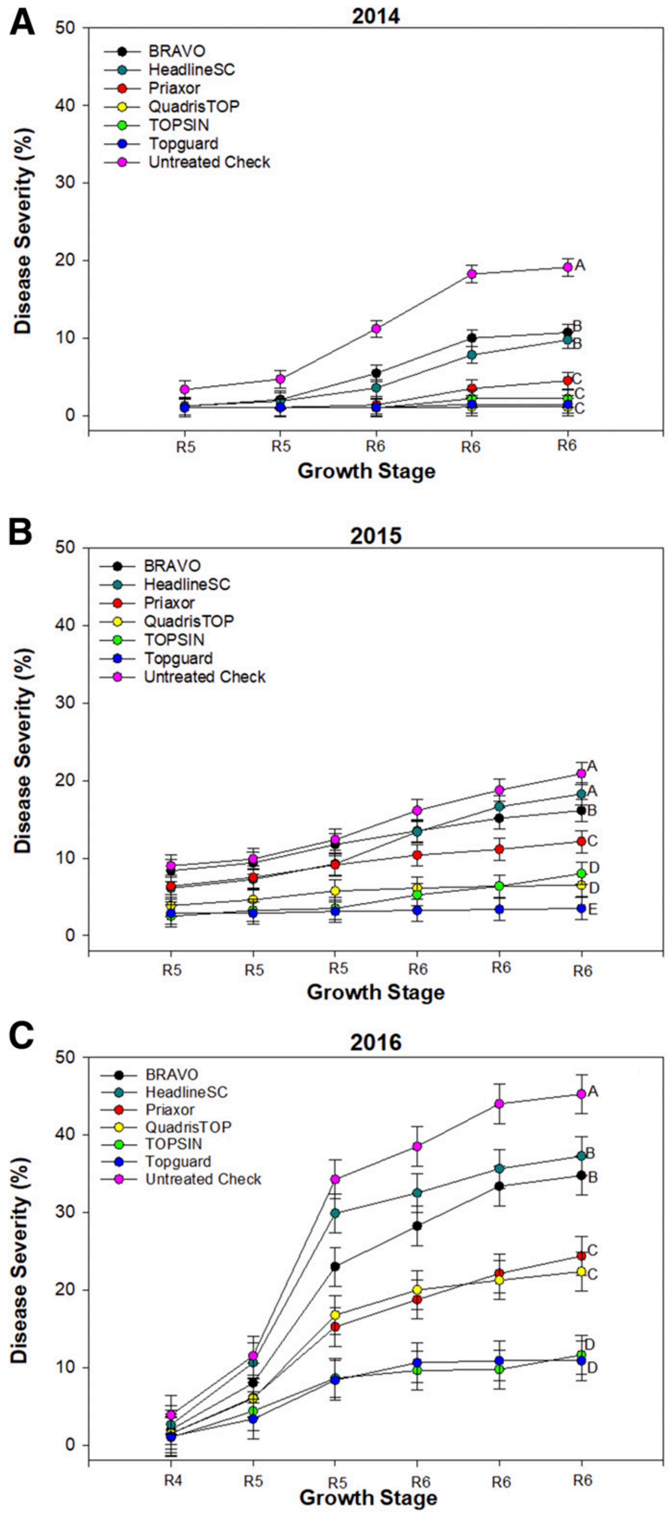

FIGURE 3

Disease severity ratings of frogeye leaf spot on soybean cultivar Asgrow 4832 treated with six fungicide treatments and an untreated control in field plot study at Milan, TN in 2014 (**A**), 2015 (**B**), and 2016 (**C**). The maximum disease severity rating shows the means; means followed by the same letter are not significantly different from each other ($P \leq 0.05$) based on Fisher's least significant difference test.

fungicide group, which Headline SC solely contains (pyraclostrobin). Bravo has historically provided poor control of FLS (personal communication from Melvin Newman), which could be compounded by its contact, nonsystemic action. Fungicides containing an active ingredient in the MBC (FRAC 1) or DMI (FRAC 3) groups, however, reduced disease severity and protected yield significantly.

The greater disease control Headline SC provided in 2014 compared with other years suggests that the FLS pathogen population may have had a greater QoI fungicide-sensitive proportion, while over time QoI fungicide resistance increased, resulting in the decreased efficacy in 2015 and 2016. Fungicide application in 2016 resulted in greater yield increases above the untreated check in 2014 and 2015 but did not prevent FLS from negatively impacting yield (Figs. 3 and 4) in a greater disease environment. Thus, FLS can be an important disease, especially when soybean yield potential is high.

TABLE 4
Percent frogeye leaf spot control based on the maximum disease severity[z]

Fungicide	2014	2015	2016	Average
Bravo	45 b	24 b	22 b	30
Headline SC	50 b	14 a	18 b	27
Priaxor	75 c	43 c	47 c	55
Topsin	85 c	62 d	73 d	73
Topguard	90 c	81 e	76 d	82
Quadris TOP SBX	95 c	67 d	51 c	71
Average	73	48	48	57

[z] Maximum disease severity was calculated as [(untreated – treated)/untreated] × 100. Means followed by the same letter are not significantly different from each other ($P \leq 0.05$) based on Fisher's least significant difference test.

Results from this study corroborate previous reports that FLS was suppressed and yield was protected with fungicide applications. This is in agreement with Dorrance et al. (2010) and Mengistu et al. (2014) that FLS contributes to yield loss in soybeans. Paired comparisons between yields in fungicide-treated and untreated checks indicated that there was greater and more consistent yield increase from Topsin and Quadris TOP SBX fungicides than the other fungicides across all three years, which suggests that these two fungicides were most effective and may be used to protect yield from the QoI-fungicide-resistant *C. sojina* strains. However, solo use of Topsin for FLS is at high risk for fungicide resistance development; hence, mixing Topsin with another mode of action (FRAC group) fungicide is recommended to decrease the risk of developing MBC fungicide resistance. There are fungicide combination products labeled for FLS in soybean that contain the active ingredient of Topsin, thiophanate-methyl, and an additional active ingredient from a different FRAC group, usually a DMI. Such premixed, combination fungicides could provide similar disease control and yield protection but could vary based on the amount of thiophanate-methyl and efficacy of the other fungicide component. Quadris TOP SBX is a fungicide combination product containing both a DMI and QoI component, which can reduce fungicide resistance development. However, with QoI resistance already present in the FLS pathogen population, it is debatable if the product is putting too much selection pressure on the population for DMI fungicide resistance. FLS is caused by a highly variable pathogen with many races (Phillips 1999), and both tilled and no-till plots can provide the conditions for variation and for the presence of fungicide-resistant isolates, thus complicating fungicide recommendations. Our results showed that control of FLS could be

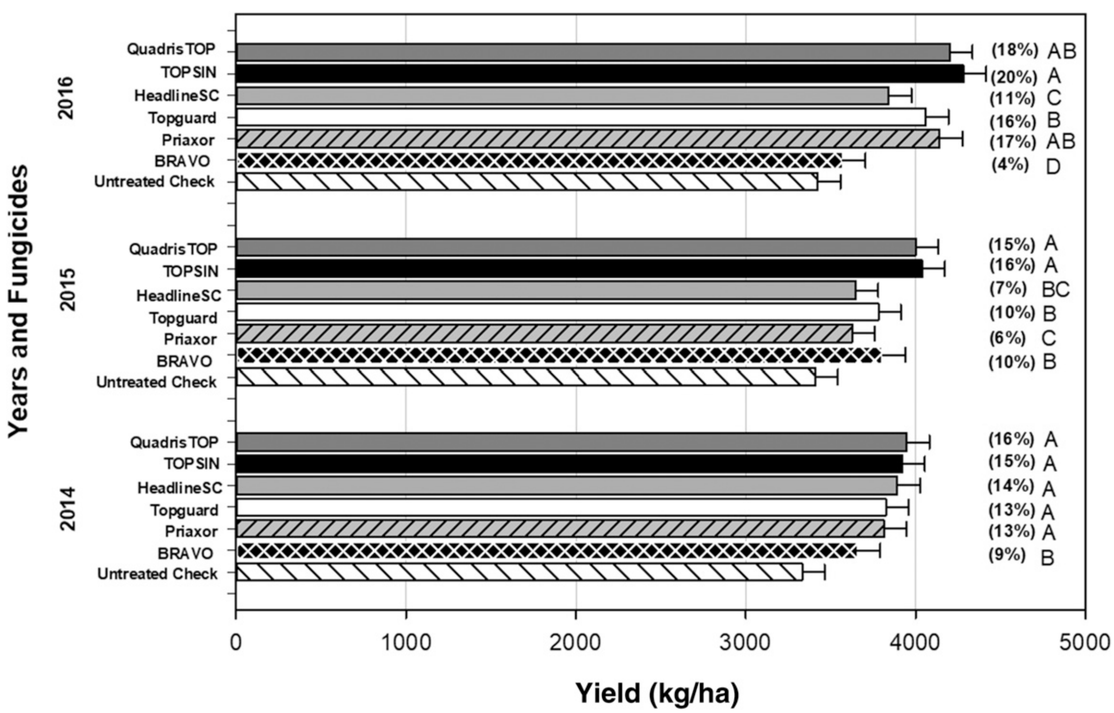

FIGURE 4

Year × fungicide interaction on yield (kg/ha) and percent yield difference from the untreated check of soybean cultivar Asgrow 4832 planted at the Research and Education Center, University of Tennessee, Milan, TN, in 2014, 2015, and 2016. Percent yield protected indicated in parentheses was calculated as [(treated – untreated)/treated] × 100.

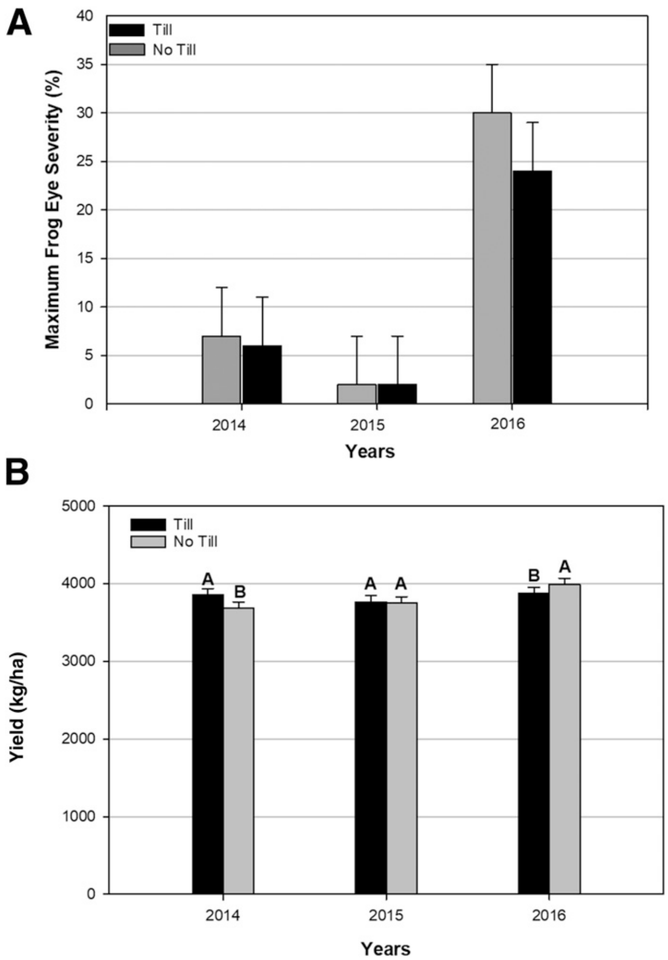

FIGURE 5

Least square means of tillage × year interactions for maximum frogeye severity (%) measurement (**A**) and yield (kg/ha) (**B**) across fungicides in till and no-till on soybean cultivar Asgrow 4832 planted in 2014, 2015, and 2016. Yield means with the same letter within each year are not significantly different at $P \leq 0.05$.

achieved using selected fungicides with different modes of actions. Although combination products are among the most effective in controlling FLS and protecting yield in the field, long-term use may exert selection for fungicide resistance. To lower the risk of resistance from *C. sojina*, it is imperative to couple effective fungicides with host resistance, which could have a major impact for lasting and effective FLS management.

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