Impact of Brown Spot Caused by *Septoria glycines* on Soybean in Ohio

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ABSTRACT

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Brown spot, caused by *Septoria glycines*, is the most common foliar disease of soybean in Ohio, but its economic impact has not been assessed on modern cultivars. Therefore, the objectives of this study were to (i) evaluate the effect of *S. glycines* on soybean yield and (ii) evaluate the efficacy of strobilurin- and triazole-based fungicides on the control of brown spot. Yield loss associated with *S. glycines* was determined using weekly applications of chlorothalonil. The efficacy of azoxystrobin, pyraclostrobin, tebuconazole, and flutriafol alone and in combinations were also assessed using applications at the R3 and R5 growth stages at two locations over 3 years. Significantly different levels of brown spot developed following applications of chlorothalonil, with mean yield differences between treated and nontreated plots ranging from 196 to 293 kg/ha. Pyraclostrobin and azoxystrobin applied at the R3 growth stage significantly reduced final levels of brown spot; however, significant increases in yield occurred in only three of the six location-years. Triazoles, flutriafol and tebuconazole, applied at R3 or R5 did not significantly decrease levels of brown spot or impact yield. More data on the accurate timing of fungicides are still required to establish a long-term management program for this disease, and resistance to brown spot should be monitored in soybean cultivar development to prevent future yield losses.

Brown spot, a fungal leaf spot caused by *Septoria glycines* Hemmi, is a common disease of soybean (*Glycine max* (L.) Merr.) and can be found throughout the Atlantic, Midwest, and Southern states (11). Small, brown lesions develop on leaves in the lower canopy and progress up the plant as the season progresses to the mid-, then upper, canopy. Individual lesions may coalesce, and the surrounding tissue becomes chlorotic, after which premature defoliation occurs (8,11).

Yield losses attributed to *S. glycines* ranged from 12 to 17% in inoculated studies, while losses reported from natural infection were from 1 to 8% (8,9,13,16). Cooper (1) reported a 40% yield loss in surface-irrigated plots in 1980. More often, though, brown spot is believed to be a minor disease with limited effects on yield (1). In the United States, yield losses ranging from 0.6 to 2.6% of the total yield were attributed to brown spot during 1999 to 2003 and 2005 (14,15). The highest losses reported were in 2004 from Iowa and Illinois, with approximately 305,676 and 223,797 tonnes, respectively (14).

There have been few studies which evaluated the effects of fungicide on brown

spot. Pataky and Lim (8) applied benomyl to soybean cv. Williams at the R1, R3, and R6 growth stages (10) in a study at three locations. Disease severity was reduced with both inoculated and natural inoculum when benomyl was applied at the R3 or R1 plus R6 growth stages at all locations; however, yield was significantly greater at only one of the three locations. Cooper (1) also studied the effect of benomyl applications on brown spot in high-yield environments with both determinate (Hobbit and Sprite) and indeterminate (Pella and Williams) soybean cultivars. In this study, yields were significantly increased for two cultivars (Hobbit and Pella) planted in narrow rows (17-cm) but not for Sprite and Williams at both narrow and wide rows (75-cm). Benomyl applications did delay maturity between 3.3 to 9.0 days relative to the unsprayed checks, with the greatest response in the determinate cultivars.

During the past 20 years, soybean germplasm has changed, as well as the fungicides that are now labeled on soybean. There are increased reports from producers that fungicides are contributing to an increase in yields across the north-central region (4). However, there are limited data on the yield effect of *S. glycines* on new soybean cultivars as well as the level of efficacy of new fungicide active ingredients on this fungus. Therefore, the objectives of this study were to (i) evaluate the effect of *S. glycines* on soybean yield and (ii) evaluate the efficacy of strobilurin- and triazole-based fungicides for the control of brown spot.

MATERIALS AND METHODS

Field studies were conducted during 2006, 2007, and 2008 at two locations in Ohio: the Ohio Agricultural Research and Development Center (OARDC) Western Agricultural Research Station near South Charleston (Western) and the OARDC Northwestern Agricultural Research Station near Custar (Northwest). Soil types consisted of a Hoytville clay and Kokomo silt loam at the Western and Northwest Agricultural Research Stations, respectively. All studies were planted into fields following corn, which is typical of much of Ohio soybean production. Irrigation was not applied at any location.

There were no data on the resistance or susceptibility of soybean cultivars to brown spot; therefore, cultivars which were widely planted or had reported responses to fungicides were selected. In addition, cultivars with later maturities (3.1 to 3.9) for this region were selected to provide more green tissue longer into the growing season, thus providing a longer period of time for disease to develop. Four soybean cultivars were evaluated each year of the study. Soybean cv. DeKalb DKB38-52 was used at both locations in all years of the study. During 2006, Pioneer 93M92, Midwest GR 3931, and Asgrow AG3905 were also included at both locations. In 2007, Seed Consultants SC9384 was added to the study because it is also highly susceptible to frogeye leaf spot caused by *Cercospora sojina* Hara. Vistive RV2890 (low linolenic) and Pioneer 93B82, which are both resistant to *C. sojina*, were also added because they were planted over a large number of acres in the state. During 2008, Pioneer P93M92 replaced Pioneer P93B82, and Vistive RV2890 was not included at Northwest due to limited availability of seed. Soybean cv. P93B82 is sensitive to glyphosate; therefore, in 2007, conventional herbicides were used whereas, during 2006 and 2008, a glyphosate herbicide program was used. In addition, the insecticide Warrior was applied 9 September 2006, 4 September 2007, and 25 August 2008 at Northwest for management of bean leaf beetle. No insecticides were applied at Western.

Chlorothalonil applications. To study the effect of *S. glycines* on yield, weekly applications of chlorothalonil (tetrachloroisophthalonitrile) at 1.05 kg a.i./ha were made for 2, 3, 4, 5, 6, 7, 8, 9, or 10 times beginning at the V1 (fully developed leaf at unifoliate node) and ending at the R6 (full seed) growth stage (10) across all

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cultivars. This strategy allowed for different levels of brown spot to develop across the study, with the highest levels of disease in the nontreated control plots and the lowest levels in the plots that received up to 10 total applications of chlorothalonil. During 2006 and 2007, Bravo Ultrex 720 (Syngenta Crop Protection, Inc., Greensboro, NC) was used whereas Echo 720 (Sipcam Agro USA, Inc., Roswell, GA) was used during 2008.

Strobilurin and triazole applications.

A second study was conducted at each location to evaluate the effect of strobilurin and triazole fungicides on brown spot. Strobilurin-based fungicides pyraclostrobin at 0.109 kg a.i./ha (Headline; BASF Corporation, Research Triangle Park, NC) and azoxystrobin at 0.109 kg a.i./ha (Quadris; Syngenta Crop Protection Inc.), as well as the triazole-based fungicide, tebuconazole, at 0.012 kg a.i./ha (Folicur; Bayer CropScience LP, Research Triangle Park, NC), were applied alone or in combination at R3 or R5 in 2006. In 2007, azoxystrobin was replaced by flutriafol at 0.063 kg a.i./ha (Topguard; Cheminova Inc., Wayne, NJ), a triazole-based fungicide, with applications made at R1, R3, and R5 across all cultivars. During 2008, pyraclostrobin (0.109 kg a.i./ha) was applied alone at R3 or R5 or in combination with tebuconazole (0.012 kg a.i./ha) at R3 or R5 at both locations. In addition, tebuconazole (0.012 kg a.i./ha) and flutriafol (0.063 kg a.i./ha) were applied alone at either R3 or R5 at Western.

The studies were arranged in a randomized complete block design with a split-plot treatment arrangement, with soybean cultivars as the whole plot and fungicide treatments as the subplots. There were four replications, and individual plots were 3.1 m wide (16 rows with 19.1-cm spacing) by 9.1 m long, with 1.5-m alleyways between plots. Each study was planted at approximately 445,000 seeds/ha at a depth of 3.8 cm. Weed control was attained with glyphosate during 2006 and 2008 because all cultivars were tolerant. In 2007, glyphosate was also used at Northwest because three of the four cultivars were tolerant, and conventional herbicides were used at the Western location. Fungicide applications at Western were made with a tractor-mounted compressed-air sprayer and at Northwest with a power take-off sprayer. Both sprayers were calibrated to deliver a volume of 187 liter/ha at 345 kPa using TeeJet XR8003 flat-fan nozzles spaced 51 cm apart on 3-m-long booms. Harvest at both locations was limited to the center 2 m of each plot.

Disease assessment. Data collected for all studies included visual assessments of the percentage of leaf area affected (LAA) by brown spot in the soybean lower and mid-canopy at the V5 and R6 growth stages, as well as yield. One representative leaf was selected from the lower and mid-

canopy from each of four plants near the center of each plot and assessed for percent LAA. The mean percent LAA within the mid-canopy (R5 and R6) for each plot was used for statistical analysis. Diagrammatic scales were used as a point of reference to evaluate percent LAA for each year of the study. During 2006, the diagrammatic scale for assessment of soybean rust severity (3) as well as the disease assessment-training program Disease.Pro 5.1 (Iowa State University, Ames) were used. During 2007 and 2008, a scale that was specifically designed for brown spot was used. To develop the brown-spot scale, 10 soybean leaves from one cultivar, DK3852, were collected at Northwest in 2006 from the lower to mid-canopy in five treatments (0, 2, 6, 8, or 10 weekly applications of chlorothalonil) across four blocks. Leaf samples were collected at both the R3 and R7 growth stages to provide a wide range of visual brown spot severity levels. Images of these leaves were scanned, and the image analysis software for plant disease quantification, ASSESS (The American Phytopathological Society, St. Paul, MN), was used and percent LAA was recorded.

The brown spot diagrammatic scale with pictures of representative leaves with different levels of severity (Fig. 1) was then developed and used as a guide.

The center 2 m of the plots from both studies was harvested with plot combines on 10 October and 3 November 2006, 8 and 22 October 2007, and 17 and 7 October 2008 at Western and Northwest, respectively. Weights were adjusted to 13% grain moisture before analysis.

Data analysis. Each location and year was considered to be a separate environment, and percent LAA by brown spot and yield were analyzed in each environment separately using analysis of variance (Proc GLM in SAS 9.1; SAS Institute Inc., Cary, NC). Individual treatment means were separated using Fisher's protected least significant difference at $P = 0.05$. The relationship between brown spot disease severity at the R5 growth stage and yield was determined by linear regression using Proc Reg in SAS 9.1, where disease severity was the independent variable and yield the dependent variable. There was extensive flooding injury to soybean during early vegetative growth stages in several

Fig. 1. Assessment scale used to evaluate severity of brown spot, caused by *Septoria glycines*, as percent leaf area affected during 2007 and 2008. Percentage of leaf area affected was A, 0.9; B, 2.3; C, 4.5; D, 10.6; E, 17.0, and F, 19.0.

plots during both 2006 and 2008 seasons, especially at Northwest. Plots which were severely affected (<70% stand) were removed from analysis in 2006. During 2008, severe flooding injury occurred prior to fungicide application; therefore, only treatments with 0, 2, 4, 6, 7, 8, and 10

chlorothalonil sprays, pyraclostrobin at R3, pyraclostrobin at R5, pyraclostrobin plus tebuconazole at R3, pyraclostrobin plus tebuconazole at R5, and pyraclostrobin at R3 plus tebuconazole at R5 were evaluated in the nonaffected areas of the field. Location of plots was established where the

soybean was closed canopy at R2 while, in flood-injured areas, the canopy was open and flowering delayed.

RESULTS

Precipitation and temperature data were retrieved from the central storage for the OARDC weather stations (D. Lohnes, *personal communication*). Precipitation events were variable during the 3 years of this study (Fig. 2). Rainfall totals from May through September 2006 were 47.7 and 55.3 cm at the Western and Northwest locations, respectively. During the same period in 2007, total precipitation was 39.9 and 50.8 cm at each location, respectively. However, most of the precipitation occurred between August and September at both locations. In 2008, the total precipitation was 47.8 and 43.6 cm at the two locations, respectively; however, there was a period of low precipitation between August until the end of September at Western, whereas drought conditions were prevalent between mid-July and mid-September at Northwest.

For both locations in each year of the study, brown spot developed on all cultivars used in this study. Frogeye leaf spot developed on one cultivar, Seed Consultants SC9384, during 2007 at the very end of the season and at less than 5% LAA in the upper canopy.

Chlorothalonil applications. Weekly applications of chlorothalonil at all locations resulted in highly significant differences ($P < 0.0001$) in the levels of brown spot severity at the R5/R6 growth stage among chlorothalonil treatments during all 3 years of this study. The cultivars were not significantly different for brown spot disease severity in five of the six location-years, and the cultivar–chlorothalonil treatment interaction was only significant at Northwest in 2006 ($P = 0.0405$) and 2007 ($P = 0.0416$) (Table 1); therefore, data were pooled across cultivars. Overall, mean disease severity levels were higher in 2006 (Fig. 3A and D) than in 2007 (Fig. 3B and E) and 2008 (Fig. 3C and F). Treatments with 8 to 10 consecutive weekly applications of chlorothalonil had significantly less disease than the nontreated control and treatments with two to four applications (Fig. 3) at both locations during 2006 and 2007. Treatments with 8 to 10 applications were significantly different from the nontreated control and two applications during 2008.

There was a highly significant effect of the chlorothalonil treatments on yield at Western in 2006 ($P < 0.0001$), 2007 ($P = 0.0046$), and 2008 ($P = 0.0026$) (Table 1). At Northwest in 2006, the same treatments were marginally significant ($P = 0.0540$). There was no significant cultivar–chlorothalonil treatment interaction effect on yield in any of the environments. For those locations with a significant yield difference, the difference between the

Fig. 2. Precipitation levels at the Ohio Agricultural Research and Development Center Western (W) and Northwestern (NW) Agricultural Research Stations during 2006, 2007, and 2008, where the impact of *Septoria glycines* on soybean yield as well as efficacy of strobilurin and triazole fungicides on *Septoria glycines* was studied in Ohio.

nontreated control and 10 applications of chlorothalonil was 313, 104, 108, and 203 kg/ha in 2006 at Western and Northwest and in 2007 and 2008 at Western, respectively (Table 2).

There was a significant negative linear relationship ($P < 0.05$) between yield and disease severity at the R5 or R6 growth stages in all environments (Fig. 4). The estimated regression slopes (P values) were -20.1 (0.0386) and -6.6 (0.0012) in 2006, -21.8 (0.0091) and -36.0 (0.0026) in 2007, and -32.3 (0.0201) and -13.3 (0.0039) kg ha⁻¹ %LAA⁻¹ in 2008 at Western and Northwest locations, respectively. Values for the coefficient of determination (R^2) were low and ranged from 0.03 to 0.1 for the six location-years, indicating that brown spot severity explained only 3 to 10% of the variation in grain yield in this study.

Strobilurin and triazole applications. Brown spot reached the mid-canopy in all cultivars at all locations during this study, albeit at relatively low levels (1.7 to 21.2% LAA). The lower third of the soybean plants was defoliated by both brown spot and shading at the R5 growth stage; therefore, for late-season comparisons and effect on yield, disease severity data at the R5 or R6 growth stage were used. The cultivars were significantly different ($P < 0.05$) from each other in four of the six location-years for disease severity at R5, and the cultivar–fungicide treatment interaction was not significant for any of the trials (Table 3). During 2008, cultivars were significantly different for brown spot disease severity at both locations. Pioneer 93M92 (14.5% LAA) had significantly more brown spot at R5 than SC9384 (9.4% LAA) or DeKalb DK3852 (7.9% LAA) at Northwest. Pioneer 93M92 (5.8% LAA) also had significantly higher levels of brown spot at R5 than RV2890 (2.8% LAA) and DeKalb DK3852 (3.3% LAA) at Western.

The fungicide treatments were significantly different from each other for disease severity at Northwest ($P = 0.036$) in 2008, highly significantly different ($P < 0.001$) at Northwest in 2006 and 2007 and Western in 2008, while marginally significant at

Western ($P = 0.0513$) in 2007. However, the effect of fungicide on yield was significantly different at Northwest ($P = 0.026$) in 2006 and highly significant ($P < 0.001$) at both locations in 2007. Applications of strobilurins (pyraclostrobin or

Fig. 3. Percent leaf area affected with brown spot caused by *Septoria glycines* across four soybean cultivars at the Ohio Agricultural Research and Development Center **A**, **B**, and **C**, Western and **D**, **E**, and **F**, Northwest Agricultural Research Stations during **A** and **D**, 2006; **B** and **E**, 2007; and **C** and **F**, 2008 following weekly applications of chlorothalonil from growth stage V4 to R6. Percent leaf area affected was measured by rating at least four leaves in the lower canopy (bottom one-third of plant) and/or mid-canopy (middle one-third of plant). Bars from the same growth stage and location with the same letter are not significantly different using Fisher's protected least significant difference at $P = 0.05$.

Table 1. Analysis of variance for the effect of weekly applications of chlorothalonil (T) on soybean cultivars (C) for brown spot severity at growth stage R5 and yield in 3 years at Western and Northwest Ohio Agricultural Research and Development Centers near South Charleston and Custer, OH, respectively

Source	2006			2007			2008		
	df	F	P	df	F	P	df	F	P
Severity at R5									
Western									
C	3	0.84	0.5178	3	2.59	0.1173	3	2.75	0.1048
T	9	12.51	<0.0001	9	12.51	<0.0001	9	7.25	<0.0001
T × C	27	1.41	0.1267	27	0.84	0.6942	27	1.06	0.4064
Northwest									
C	3	0.74	0.5646	2	39.89	0.0003	2	1.21	0.3609
T	9	28.16	<0.0001	9	15.65	<0.0001	6	8.3	<0.0001
T × C	27	1.69	0.0405	18	1.78	0.0416	12	0.34	0.9768
Yield									
Western									
C	3	4.84	0.0285	3	23.98	0.0001	3	8.38	0.0057
T	9	5.75	<0.0001	9	2.86	0.0046	9	3.07	0.0026
T × C	27	1.46	0.0886	27	1.25	0.2100	27	0.82	0.7203
Northwest									
C	3	9.87	0.0841	2	3.18	0.1142	2	0.34	0.7254
T	9	1.99	0.0540	9	0.97	0.4749	6	1.43	0.2205
T × C	27	1.29	0.1901	18	0.52	0.9427	12	0.4	0.9587

azoxystrobin) at R3 or combinations of pyraclostrobin at R3 with tebuconazole at R3 or R5 significantly ($P < 0.05$) reduced the severity of brown spot in five of the six location-years (Fig. 5). Yields were increased between 183.7 to 490 kg/ha with fungicide treatments over the nontreated control at three of the six location-years (Table 4). Pyraclostrobin alone at R3 was

significantly different from the nontreated control in 2006 (232 kg/ha) and 2007 (300 kg/ha) at Northwest. Pyraclostrobin plus tebuconazole applied at R3 in had significantly higher yields of 170 and 490 kg/ha in 2006 and 2007, respectively, at Northwest. The only fungicide treatment that had a significantly higher yield than the nontreated control at the 2007 Western location

(383 kg/ha) was pyraclostrobin applied at R3 followed by tebuconazole at R5.

DISCUSSION

Disease severity was reduced by multiple applications (six or more) of chlorothalonil as well as a strobilurin fungicide applied at R3 and, in some years, at R5. In this study, there was also a significant negative relationship between brown spot severity at the R5 or R6 growth stage and yield, albeit a maximum of 10% of the variation in yield was explained by the variation in disease in the linear regression

Table 2. Yield response of soybean to weekly applications of chlorothalonil at Ohio Agricultural Research and Development Center Western (W) and Northwest (NW) Agricultural Research Stations near South Charleston and Custer, OH, respectively^y

No. of sprays	Yield (kg/ha) ^z					
	2006		2007		2008	
	W	NW	W	NW	W	NW
0	2,973 de	3,152 b	4,011 d	3,830 a	4,221 bcd	1,979 a
2	3,184 bc	3,157 b	4,157 abc	3,789 a	4,156 d	2,164 a
3	3,093 cde	3,184 b	4,062 bcd	3,892 a	4,181 cd	NT
4	3,123 bcd	3,198 ab	3,953 d	3,810 a	4,418 ab	2,218 a
5	3,005 de	3,206 b	4,105 abcd	3,824 a	4,435 ab	NT
6	2,960 e	3,273 ab	4,123 abcd	3,797 a	4,389 abc	2,150 a
7	3,191 abc	3,327 ab	4,042 bcd	4,007 a	4,491 a	2,143 a
8	3,279 ab	3,388 a	4,282 a	4,014 a	4,423 ab	2,184 a
9	3,354 a	3,361 a	4,270 a	3,980 a	4,479 a	NT
10	3,286 ab	3,293 ab	4,210 ab	3,919 a	4,504 a	2,028 a
Mean	3,145	3,254	4,122	3,886	4,374	2,124

^y Chlorothalonil was applied at 1.05 kg a.i./ha.

^z Yields were adjusted to 13% grain moisture; numbers within a column followed by same letter are not significantly different using Fisher's protected least significant difference at $P = 0.05$; NT indicates not tested.

Fig. 4. Relationship between brown spot severity and yield for experiments conducted in **A** and **D**, 2006; **B** and **E**, 2007; and **C** and **F**, 2008 at the Ohio Agricultural Research and Development Center **A**, **B**, and **C**, Western and **D**, **E**, and **F**, Northwest Agricultural Research Stations in Ohio. Each point represents data for one plot from experiments using applications of chlorothalonil fungicide on several soybean cultivars.

Fig. 5. Mean brown spot severity levels in response to applications with strobilurin, triazole, or strobilurin plus triazole fungicides at soybean growth stages R3 and R5 at the Ohio Agricultural Research and Development Center Western (W) and Northwest (N) Agricultural Research Stations in Ohio during **A**, 2006; **B**, 2007; and **C**, 2008. Bars with the same letter are not significantly different using Fisher's protected least significant difference at $P = 0.05$.

analysis. Overall yield losses due to brown spot in these studies ranged from 2.5 to 9.5%. This emphasizes the idea that brown spot may have a larger impact on yield in some years than was previously believed.

Pataky and Lim (9) reported that brown spot severity evaluated at the R5 growth stage correlated best with yield reductions as well as the vertical progress of the disease evaluated at the R6 growth stage. In addition, the final disease severity levels were much lower in this study compared with those reported previously from inoculated studies (7) but were more representative of the final disease levels present in producers' fields in Ohio (2). This may explain, in part, the relatively minor differences in yield from the fungicide applications in these studies.

Lim (7) reported that both soybean growth stage and weather conditions influ-

enced the development of brown spot. Low levels of precipitation and high temperatures reduced the overall rate of development, and infection rates were much higher when plants were inoculated at the R4 and R5 growth stages. In this study, precipitation levels were low overall during 2008, and resulting lower disease levels may partly explain the lack of a consistent response to the fungicide applications. Overall, when there was a yield response to the fungicide applications, brown spot severity was also decreased. From this 3-year study, under these conditions, it can be concluded that brown spot in Ohio does contribute to reductions in yield, albeit at 196 to 293 kg/ha.

Strobilurin fungicides alone or in combination with a triazole applied at the R3 growth stage were associated with both reduced severity of brown spot and yield

increases. Foliar fungicides have not been recommended for routine management of brown spot. Recently, Swobodo and Pederson (12) evaluated the effects of foliar fungicide applications to soybean at growth stages R1, R3, and R5 and reported that there was no increase in seed yield over nontreated controls.

The reduction in brown spot severity is similar to the effects reported earlier for applications of benomyl under conditions of natural inoculum (1,8). Thus, management of brown spot may partly explain some of the yield responses reported by Ohio soybean producers when strobilurin fungicides were applied to currently available cultivars.

Interestingly, there were some differences in the final levels of disease severity among the cultivars used in this study. Resistance to *S. glycines* has been reported

Table 3. Analysis of variance for the effects of fungicide treatments (F) and soybean cultivars (C) on disease severity (percent leaf area affected) of brown spot and yield in 3 years at Western and Northwest Agricultural Research Stations near South Charleston and Custer, OH, respectively

Source	2006			2007			2008		
	df	F value	P value	df	F value	P value	df	F value	P value
Severity									
Western									
C	3	6.59	0.0119	3	4.40	0.0364	3	4.79	0.0292
F	9	1.00	0.4429	9	1.96	0.0513	8	6.42	<0.0001
F × C	27	0.85	0.6764	27	0.87	0.6531	24	1.12	0.3391
Northwest									
C	3	2.57	0.1190	2	2.21	0.1905	2	7.11	0.0482
F	9	3.54	0.0007	9	3.28	0.0019	5	2.79	0.0365
F × C	27	1.06	0.4062	18	1.10	0.3682	10	1.53	0.1791
Yield									
Western									
C	3	11.73	0.0018	3	6.32	0.0832	3	2.39	0.0126
F	9	1.88	0.0624	9	4.16	0.0001	8	1.48	0.1733
F × C	27	0.87	0.6482	27	1.01	0.4563	24	1.74	0.0284
Northwest									
C	3	2.44	0.1317	2	5.53	0.0434	2	0.01	0.9877
F	9	2.22	0.0260	9	4.56	<0.0001	5	1.7	0.1670
F × C	27	1.29	0.1780	18	0.55	0.9221	10	0.39	0.9410

Table 4. Yield response of soybean to timed applications of azoxystrobin, pyraclostrobin, flutriafol, or tebuconazole fungicides at Ohio Agricultural Research and Development Center Western (W) and Northwest (NW) Agricultural Research Stations near South Charleston and Custer, OH, during 3 years

Fungicide treatment ^a	Timing ^a	Yield (kg/ha) ^x					
		2006		2007		2008	
		W	NW	W	NW	W	NW
Nontreated 1	...	4,212 a	3,143 c	4,373 c	4,252 d	4,001 a	2,191 a
Nontreated 2	...	4,375 a	3,273 abc	NT	NT	NT	NT
Flutriafol	R1	NT	NT	4,370 c	4,300 d	NT	NT
Pyraclostrobin	R3	4,491 a	3,375 a	4,331 c	4,552 abc	4,191 a	2,286 a
Tebuconazole	R3	4,497 a	3,164 bc	4,402 bc	4,327 cd	3,980 a	NT
Pyraclostrobin + tebuconazole	R3	4,443 a	3,313 ab	4,601 ab	4,742 a	4,157 a	2,123 a
Flutriafol	R3	NT	NT	4,256 c	4,348 cd	4,042 a	NT
Azoxystrobin	R3	4,218 a	3,368 a	NT	NT	NT	NT
Pyraclostrobin	R5	4,450 a	3,327 a	4,400 bc	4,552 abc	4,198 a	2,164 a
Tebuconazole	R5	4,429 a	3,252 abc	4,323 c	4,239 d	4,137 a	NT
Pyraclostrobin + tebuconazole	R5	4,674 a	3,286 abc	NT	NT	NT	2,143 a
Flutriafol	R5	NT	NT	4,336 c	4,470 bcd	4,110 a	NT
Pyraclostrobin then tebuconazole	R3/R5	4,470 a	3,164 bc	4,756 a	4,667 ab	4,144 a	2,136 a
Mean	...	4,426	3,267	4,415	4,445	4,107	2,174

^x Yields were adjusted to 13% grain moisture; numbers within a column followed by the same letter were not significantly different using Fisher's protected least significant difference at $P = 0.05$; NT indicates not tested.

^y Fungicides were applied at the following rates: pyraclostrobin at 0.109 kg a.i./ha, azoxystrobin at 0.109 kg a.i./ha, tebuconazole at 0.012 kg a.i./ha, and flutriafol at 0.063 kg a.i./ha.

^z Timing of fungicide applications was at soybean growth stages R1, R3, and R5 (10).

previously as differences in the rate of disease development (5–7). Cooper (1) also noted differences in final disease levels among cultivars within both semidwarf and indeterminate cultivars. This is not a factor that has been well studied recently, and these data indicate that it should receive some additional attention in the future, especially as cultivars with new traits are introduced into the marketplace. Cultivars targeted for Ohio, especially those for narrow-row and no-till production systems, should have moderate to high levels of resistance to *S. glycines*.

S. glycines is a very common foliar pathogen found in production fields throughout Ohio which can be managed with strobilurin fungicides applied at the R3 growth stage. Triazole fungicides had no efficacy in this study. These fungicide applications were aimed at reducing the overall level of disease but the response was highly influenced by the overall susceptibility of the cultivar as well as precipitation events. Cooper (1) previously demonstrated that fungicide applications in irrigated high-yield environments can be beneficial. However, it is important to consider the economic thresholds of these fungicide applications to determine whether producers can recover their costs. As such, the costs associated with application would need to be much lower than the return of 196 to 293 kg/ha. Overall input costs have increased substantially for soybean production in the past 5 years, primarily from seed costs, and the price of grain has also been quite volatile. In addition to the economics of these applications, the potential for the development of resis-

tance to strobilurins by *S. glycines* should be determined prior to widespread incorporation of this management tool into soybean production systems. More accurate timing of fungicides will be needed to establish a long-term management program for this disease as well as monitoring resistance levels to brown spot as a feature in soybean cultivar development for Ohio.

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