Effect of Wheat Residue and Tillage on *Heterodera glycines* and Yield of Doublecrop Soybean in Kentucky

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ABSTRACT

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A study (1990 to 1992) was conducted in western Kentucky to determine the effects of wheat (*Triticum aestivum* 'Clark') residue and minimal- (two disking) or no-tillage on soybean cyst nematode (*Heterodera glycines*) cyst and egg population densities and yield of the *H. glycines*-susceptible soybean (*Glycine max*) cultivar Pennyrile. In each year, cyst densities at soybean planting were unaffected by the presence of residue from a prior winter wheat crop; however, harvest population densities were lower in plots with wheat residue compared with those without residue. Across residue treatments, tillage had no effect on harvest densities of cysts in any year. Differences in egg densities, determined only in 1992, were similar to differences detected in cyst densities for both residue and tillage. Minimum-tillage of wheat residue significantly reduced the "residue effect" in 1990 and 1991; however, plots with wheat residue had fewer cysts at harvest than plots without residue in both years regardless of tillage method. Neither residue nor tillage affected soybean yields. Results indicate that producers who have the option to no-till doublecrop soybean following wheat may have an advantage in long-term management of *H. glycines*.

The effects of tillage methods employed in crop production on *Heterodera glycines* Ichinohe, soybean cyst nematode (SCN), population dynamics have been the focus of various studies (2–4,10,12–15). *H. glycines* numbers are reduced when populations are subjected to long-term, no-till production systems compared with conventional tillage systems. The short-term effects of tillage on *H. glycines* populations also have been studied.

Baird and Bernard (2) detected lower numbers of SCN second-stage juveniles (J2) in samples collected during July where soybeans were planted in no-till plots compared to samples from conventional tillage plots. In contrast, late-season J2 densities and mid- and late-season cyst densities were unaffected by tillage. In a North Carolina study (14), egg densities were greater 2 months after planting in conventional than in no-till plots. Chambers (3) reported that cyst densities in conventionally tilled plots increased three- to sixfold from planting to harvest, whereas those in no-till plots increased up to twofold over the same time period. Edwards et al. (4) and Tyler et al. (14) reported similar results. Young (17) simulated conventional- and no-tillage treatments in greenhouse studies and found that three times more *H. glycines* females developed in disturbed soil than in nondisturbed soil after 30 days. Wrather et al. (16) reported that harvest densities of cysts were lower in no-till plots compared with those subjected to minimum tillage.

In each of the mentioned studies, no-till soybeans (*Glycine max* (L.) Merr.) were planted in prematurely killed wheat (*Triticum aestivum* L.) (2,4,14) or soil with residue from harvested wheat (3,11,16,17). Thus, the possible effects of wheat residue on *H. glycines* could not be separated from effects of tillage.

In any given year, nearly one-third of the soybeans produced in Kentucky are doublecropped after wheat (6). The majority of doublecropped soybeans are planted no-till, although planting in minimum-tilled (disked) wheat residue also is common. Moreover, no-till, full-season soybean production, which does not include wheat production, also is employed regularly and is increasing due to concerns about soil erosion and water quality (6). Thus, our objectives were to determine if *H. glycines* is affected by wheat residue and tillage method. These questions must be answered if appropriate management recommendations relating to tillage and doublecrop soybean are to be developed.

MATERIALS AND METHODS

The experiment was conducted from 1990 to 1992 in commercial fields in western Kentucky that were in a corn-wheat/soybean rotation for many years. The 1990 study was conducted in Caldwell County in a field of Crider silt loam (3.6% sand, 80% silt, 16.4% clay, 3.2% organic matter, pH 7.3). The 1991 and 1992 studies were conducted in fields of Pembroke silt loam in Christian County (2.3% sand, 80.1% silt, 17.6% clay, 4.4% organic matter, pH 6.9) and Todd County (3.2% sand, 75.8% silt, 21% clay, 3.7% organic matter, pH 7.1), respectively. All three test sites were infested with SCN race 3 (5).

Test fields were planted by the farmer/cooperator to conventionally tilled soft red winter wheat (*T. aestivum* 'Clark') in 17.5-cm rows during the fall of each year. During late February to early March, 6.1-m-wide × 6.1-m-long plots were laid out in dormant wheat fields to accommodate four treatments. Wheat in selected plots was killed with either glyphosate (275 g a.i./ha) (1990) or paraquat (172 g a.i./ha) (1991 to 1992). All plots, including those with killed or dying wheat, were fertilized by the cooperators with ammonium nitrate (33% N) at 40.8 to 45.4 kg/ha just prior to stem erection (mid- to late March). The rate and timing of nitrogen application is standard for wheat production in western Kentucky (11). Wheat was allowed to mature in plots not treated with herbicide, and the wheat was harvested by the cooperators on 25, 17, and 22 June 1990, 1991, and 1992, respectively. Plots in which wheat was killed prior to crop green-up were periodically sprayed with glyphosate (275 g a.i./ha) to keep them free of weeds until adjacent wheat was harvested.

On the day soybeans were planted (26, 17, and 24 June 1990, 1991, and 1992, respectively), but prior to tillage and planting, all plots were sampled to determine initial *H. glycines* cyst population densities. Soil samples consisted of six soil cores (2.5 cm diameter × 15 cm deep) taken within the center 4.9 m of each 6.1-m plot. Samples were mixed thoroughly and stored at 4°C before processing. *H. glycines* cysts were extracted from soil by wet sieving and centrifugation. In 1992, egg and J2 densities also were determined. After cysts were enumerated, eggs and J2 (hereafter referred to as eggs) were liberated from cysts with a glass tissue macerator and counted.

After soil samples were collected, minimum-tillage plots (both with and without wheat) were disked twice by the cooperator to a depth of 15 to 20 cm. Plots were planted to the soybean cultivar Pennyrile (maturity group IV, *H. glycines* susceptible), using a no-till soybean drill adapted for plot use. Each plot contained

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eight rows spaced 76 cm apart. The seeding rate was 26 seeds per m.

The experimental design was a 2 × 2 complete factorial, with two tillage regimes (minimum- and no-till) and two residue levels (wheat residue [+residue] and no wheat residue [–residue]), arranged in a randomized complete block, with three replications in 1990 and five replications in 1991 to 1992.

Weeds were controlled with alachlor (367 g a.i./ha) applied preemergence in 1990. In 1991, glyphosate (275 g a.i./ha) was applied preemergence, and fomesafen (45.8 g a.i./ha) and fluazifop-*p*-butyl (22.9 g a.i./ha) were applied postemergence. In 1992, glyphosate (275 g a.i./ha) was applied preemergence, and fomesafen (45.8 g a.i./ha) and fluazifop-*p*-butyl (34.4 g a.i./ha) were applied postemergence.

In addition to soil samples collected prior to planting soybeans each year, samples also were collected immediately prior to soybean harvest. These samples were collected, processed, and enumerated as previously described, except that soil cores were removed from within the root zones of the center two rows in each plot.

Plots were not harvested in 1990 due to deer feeding in plots. In 1991 and 1992, 4.9 m of the center two rows in each plot were hand-harvested and threshed to obtain yields. The dates of plot harvest in 1991 and 1992 were 16 and 26 October, respectively. Plot yields were based on 11.7% moisture and a test weight of 77.2 kg/hl.

Data were subjected to analysis of variance. Statistical tests on cyst and egg population densities were performed on $\log_{10(x+1)}$-transformed data to normalize the variance.

RESULTS

In each year, preplant *H. glycines* cyst population densities were similar for the various treatments (Table 1). However, cyst densities at harvest were significantly less in the presence of wheat residue every year (Table 1). Across tillage treatments, 57.1, 56.6, and 58.1% fewer cysts developed in the +residue plots compared with –residue plots in 1990, 1991, and 1992, respectively. Similar differences in egg densities were detected in 1992. Across all residue treatments, cyst and egg densities at harvest were unaffected by tillage method in all years.

A tillage × residue interaction was detected among harvest population densities in 1990 ($P = 0.009$) and 1991 ($P = 0.006$) but not in 1992. In the years in which an interaction was detected, minimum-tillage +residue plots had significantly higher cyst densities than no-till +residue plots (Table 1). In the absence of wheat residue, *H. glycines* densities at harvest were unaffected by tillage in 1991 and 1992 (Table 1). In 1990, however, 26.8% fewer cysts developed where soybeans were planted in no-tillage compared with minimum-tillage plots.

Soybean yields were not determined in 1990 because of deer feeding in plots. In 1991 and 1992, yields were unaffected by wheat residue across tillage treatments or tillage treatment across residue treatments (Table 1). A tillage × residue interaction ($P = 0.05$), however, was detected for yield in 1991. No-till +residue plots had significantly higher yields than minimum-till plots with or without wheat residue. Yield in the no-till +residue plots, however, was not significantly different from no-till –residue plots.

DISCUSSION

In this study, wheat residue associated with wheat/soybean doublecropping significantly reduced the number of *H. glycines* cysts (1990 to 1992) and eggs (1992) in soil at soybean harvest. This "residue effect" was significantly reduced by minimum-tillage of wheat residue prior to soybean planting in 2 of 3 years. Nonetheless, cyst and egg densities were always lower when wheat residue was present compared with treatments without wheat residue, regardless of tillage method.

Our findings suggest that reduced *H. glycines* reproduction in short-term no-till systems, as found in other studies (2–4, 12,14,16,17), may have been due to the presence of wheat residue and not to no-till per se. The current work suggests that the short-term effect of tillage on *H. glycines* is important relative to disturbance of wheat residue in the system. This might explain the findings reported by Koenning and Anand (9) who discounted any effect of wheat residue on *H. glycines* in wheat/soybean doublecrop systems. In their study,

Table 1. Effect of tillage and wheat residue on *Heterodera glycines* cyst (1990 to 1992) and egg (1992) population densities and yield of soybean doublecropped following soft red winter wheat

	1990		1991			1992				
	Cysts/473 cm³ soil		Cysts/473 cm³ soil		Soybean yield (kg/ha)[a]	Cysts/473 cm³ soil		Eggs/100 cm³ soil		Soybean yield (kg/ha)[a]
Treatment	**Planting**	**Harvest**	**Planting**	**Harvest**		**Planting**	**Harvest**	**Planting**	**Harvest**	
Tillage										
No-till	362	255	64	354	2,741	99	92	4,167	2,731	3,729
Minimum-till[b]	326	274	60	405	2,520	103	84	4,702	2,625	3,796
Treatment comparison[c]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Residue[d]										
–Residue	321	440	60	529	2,607	95	124	4,146	3,908	3,790
+Residue	366	189	67	230	2,647	107	52	4,724	1,448	3,709
Treatment comparison	NS	$P = 0.001$	NS	$P = 0.001$	NS	NS	$P = 0.001$	NS	$P = 0.002$	NS
Residue × Tillage										
–Residue										
No-till	347	372	62	542	2,688	94	132	3,938	3,784	3,749
Minimum-till	296	508	50	515	2,520	95	116	4,354	4,031	3,830
Treatment comparison	NS	$P = 0.01$	NS	NS	NS	NS	NS	NS	NS	NS
+Residue										
No-till	376	138	58	166	2,802	103	51	4,397	1,466	3,662
Minimum till	356	241	68	294	2,520	110	52	4,780	1,430	3,756
Treatment comparison	NS	$P = 0.05$	NS	$P = 0.05$	$P = 0.05$	NS	NS	NS	NS	NS

[a] Yields in 1991 and 1992 are based on 11.7% moisture and a test weight of 77.2 kg/hl; yields were not collected in 1990 because of deer feeding in plots.

[b] Minimum-till plots were disked twice.

[c] Analysis of variance was performed using $\mathrm{Log}_{10(x+1)}$-transformed data; NS = not significant, $P > 0.05$.

[d] Residue present after a harvested crop of soft red winter wheat: –residue = no residue; +residue = residue present.

wheat residue was conventionally tilled prior to planting soybeans; minimum- and no-till systems were not studied. It is likely that conventional tillage may have negated the residue effect by severely disturbing the wheat residue in the system.

Soybean yields were unrelated to the residue effect in 1992. In 1991, yields were higher in no-till +residue plots than in minimum-till +residue plots. However, the fact that yield in the no-till +residue treatment was not different from that of no-till –residue, even though *H. glycines* cyst densities at harvest were markedly different, suggests that yield differences were due to factors other than *H. glycines*.

Our findings indicate that the residue effect may be of limited value in preventing yield losses when susceptible soybean is grown in fields infested with damaging levels of *H. glycines*. This result is not surprising because yield relationships with *H. glycines* are dependent on preplant *H. glycines* population densities (1), which were unaffected by wheat residue in our study. However, the effect may be useful, along with nonhost crops and *H. glycines*-resistant soybean cultivars, in long-term management of *H. glycines* populations. *H. glycines* population densities increase rapidly when susceptible cultivars are grown (15). If this increase can be minimized by doublecropping soybeans after wheat, then less time will be needed to bring *H. glycines* below damage threshold levels in subsequent years. This situation may provide for less producer reliance on resistant cultivars, which is desirable due to the link between these cultivars and *H. glycines* race shifts (18). Producers also may have greater flexibility in making decisions regarding the production of nonhost crops.

Although this study establishes the effect of wheat residue on *H. glycines* in typical wheat/soybean doublecrop systems in Kentucky, the cause is unknown. It is possible that the paraquat (1990) and glyphosate (1991 to 1992) used to kill wheat may have resulted in the higher *H. glycines* populations observed in –residue plots; however, this is unlikely since both herbicides become biologically inactive and degrade rapidly after application (8) and 4 months separated herbicide application and soybean planting. The fact that cyst and egg densities at planting were not significantly different among any treatment in each year adds further evidence that *H. glycines* was unaffected by herbicides used to kill wheat.

Planting soybean in no-till standing wheat residue does not consistently reduce *H. glycines* population densities, as found in other studies (2,10,12,16). This suggests that the mechanism responsible for the residue effect may be location specific or environmentally sensitive.

In our study, cyst (1990 to 1992) and egg densities (1992) at planting were unaffected by wheat production through wheat harvest. Koenning and Anand (9) and Tyler et al. (14) reported similar findings, suggesting that the residue effect cannot be explained by the production of wheat alone. Baird and Bernard (2) suggested that toxins or metabolites active against *H. glycines* may be present in wheat and wheat residue. Others (13,14) have suggested that no-till systems (with wheat) may alter the composition of soil microbes, increasing population densities of those that attack *H. glycines*. Still others (2,14) have suggested that modifications in the soil environment may be responsible for no-till effects.

Preliminary studies (7) indicate that soil environment (increased soil moisture and decreased soil temperatures when wheat residue is present) does not totally account for the residue effect and that the maximum residue effect requires the presence of both wheat straw and wheat crowns or roots. Additional studies are needed to determine the source of the residue effect. Insight into the source may provide soybean producers with the ability to maximize the residue effect in *H. glycines* management programs.

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