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Evaluation of Pea and Soybean as Trap Crops for Managing *Heterodera glycines*[1]

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Abstract: Trap crops that stimulate nematode egg hatching but not reproduction have been reported as an effective means for managing certain nematodes. Studies were carried out at two field sites each year in 1998 and 1999 to evaluate the potential of trapping the soybean cyst nematode (*Heterodera glycines*) with soybean and pea in the corn year to manage the nematode in Minnesota. The trap crops were planted on the same day as corn at each site and later killed with the herbicide glyphosate. Nematode egg densities were determined at planting, 1 and 2 months after planting, and at harvest. Treatments included four seeding rates (0, 124,000, 247,000, and 494,000 seeds/ha) of resistant soybean as a trap crop and four kill dates (3, 4, 5, and 6 weeks after planting). No effects of the trap-crop and kill-date treatments on *H. glycines* population density, corn yield, and the following-year soybean yield were observed at the two locations. In a second study, the experiment included four trap-crop comparisons (resistant soybean at 494,000 seeds/ha, susceptible soybean at 494,000 seeds/ha, pea at 1,482,000 seeds/ha, and no trap crop) and five kill dates (3, 4, 5, 6 weeks after planting, and no-kill). At the Waseca site, egg density at harvest was lower where resistant soybean was grown for 6 weeks and where pea was grown for 5 and 6 weeks compared with where no trap crop was grown. Maintaining pea plants for more than 5 weeks, however, reduced corn yield by 20% at the Waseca site. At the Lamberton site, egg density at harvest was lower where the susceptible soybean was grown for 5 weeks compared with where no trap crop was grown. Even with significant reduction of eggs in some treatments, use of soybean and pea as trap crops in the corn year was not an effective means for managing *H. glycines*.

Key words: *Glycine max, Heterodera glycines*, management, pea, *Pisum sativum*, soybean, soybean cyst nematode, trap crop.

Soybean cyst nematode, *Heterodera glycines* Ichinohe, is a major yield-limiting pest of soybean (*Glycine max* (L.) Merr.). Management of *H. glycines* has largely relied on planting resistant cultivars and use of crop rotation. These two strategies have limitations and sometimes are not effective or practical. A resistant cultivar may not perform well when *H. glycines* density is too high. Growing a non-host crop such as corn, wheat, cotton, or sorghum for 1 to 2 years reduced *H. glycines* population density below a damage threshold in the southern United States (Koenning et al., 1993; Schmitt, 1991; Francl and Dropkin, 1986). In the northern United States, however, the *H. glycines* survival rate may be higher (Riggs et al., 2001), and a longer rotation may be needed for effective management. In southern Minnesota, where *H. glycines* has become widespread, corn-soybean annual rotation is the predominant cropping system. One year of the non-host corn reduces *H. glycines* egg density by 20 to 80% depending on field conditions and year, and after a crop of susceptible soybean it may take approximately 5 years of corn to reduce *H. glycines* density below the soybean damage threshold (Chen et al., 2001b). Therefore, additional means are needed for effective long-term management.

Trap crops have been explored for managing various nematodes (Heijbroek, 1996; Kerr, 1994; Koch and Gray, 1997; LaMondia, 1996; Whitehead, 1977; Whitehead and Turner, 1998). Mechanisms for trapping nematodes with plants vary depending on the interaction between the plant and nematode species. If a cultivar or plant species is resistant to nematode development but not resistant to nematode penetration, the cultivar or species may be used as a trap crop in rotation with a susceptible host crop (Koch and Gray, 1997) or interseeded with a non-trap crop to reduce the nematode population density. A susceptible host plant also can be used as a trap crop when the plants are destroyed or removed from the field before the nematodes have reproduced on the plants (LaMondia and Brodie, 1986; Mugniery and Balandras, 1984). Some plant-parasitic nematodes have evolved a dormancy mechanism as a survival strategy (Evans, 1987). The eggs of these nematodes may not hatch without hatching factors from hosts, resistant plants, or non-host plants. A plant species that can stimulate cyst nematode egg hatching to J2, which won't survive for more than a few weeks in the soil, also may be used as a trap crop.

Heterodera glycines is one species of which some eggs undergo dormancy (Hill and Schmitt, 1989; Yen et al., 1995). Exudates from soybean may break the dormancy and stimulate *H. glycines* eggs to hatch (Tefft and Bone, 1985). Exudates of pea, a poor host of *H. glycines* (Sortland and MacDonald, 1987), also may stimulate *H. glycines* eggs to hatch (Chen et al., unpubl.). We speculate that interseeding soybean or pea may stimulate *H. glycines* egg to hatch and reduce egg density if a susceptible soybean cultivar is planted and killed before *H. glycines* reproduction occurs, or if a resistant soybean cultivar or pea is used either with or without killing the plants. The objective of this study was to determine the potential for using soybean or pea as trap crops in the corn crop to manage *H. glycines*.

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Materials and Methods

Experiment 1: This experiment was conducted at two field sites located in southwest (Lamberton, Redwood County) and south-central Minnesota (Waseca, Waseca County) during 1998 and 1999. Soybean was grown in 1997 at both sites. The soil at the Waseca site was a clay loam with 15% sand, 46% silt, 37% clay, 8.9% organic matter, and pH 8.0; the soil at the Lamberton site was a clay loam with 42% sand, 32% silt, 26% clay, 5.0% organic matter, and pH 7.8. The *H. glycines* populations were race 3 at both sites.

The experiment was a factorial design involving four seeding rates (0, 124,000, 247,000, and 494,000 seeds/ha) of the trap crop, soybean ''Pioneer 9234,'' and four trap-crop kill dates (3, 4, 5, and 6 weeks after planting). Plots were arranged in randomized complete blocks with six replicates. Each plot consisted of four corn rows, 7.6 m long, spaced 76 cm apart. *Heterodera glycines*-resistant soybean ''Pioneer 9234'' with resistance derived from ''Peking'' was interseeded with corn rows on May 13 at the Waseca site and May 11 at the Lamberton site in 1998 with a drill planter with 19-cm-row spacings. Roundup-resistant corn ''Dekalb 493rr'' was planted at a seeding rate of 79,000 seeds/ha after the trap crop was drilled on May 13 at Waseca and on May 11 at Lamberton. Glyphosate (Roundup, Monsanto, St. Louis, MO) at 0.96 kg a.i./ha was applied on June 3, June 10, June 16, and June 24 at Waseca and on June 3, June 10, June 17, and June 26 at Lamberton to kill the soybean plants. Plots were separated by four rows of corn without interseeded soybean.

At each site, the field was moldboard-plowed in fall 1997 and field-cultivated before corn and the interseeded soybean were planted. Anhydrous ammonia was applied prior to planting at a rate of 168 kg nitrogen/ha. Alachlor (Lasso, Monsanto, St. Louis, MO) at 3.8 kg a.i./ha was used at Waseca, and metolachor (Dual II, Dow AgroSciences, Indianapolis, IN) at 2.4 kg a.i./ha was used at Lamberton to control weeds.

Nematode egg densities were determined at planting (Pi), 1 month (Pm1) and 2 months (Pm2) after planting, and at harvest (Pf). A soil sample composed of 20 soil cores was collected across an area 6.1 m × 1.5 m from each plot. Each soil core was taken to a depth of 20 cm with a 2-cm-diam. soil probe. The soil samples were stored at −20 °C in a freezer before being processed. Each soil sample was thoroughly mixed. Cysts were extracted from a subsample of 100 cm^3 soil with a semiautomatic elutriator (Byrd et al., 1976) and separated from soil particles and debris with centrifugation in 76% (w/v) sucrose solution. Eggs were released from the cysts in a 40-ml glass tissue grinder (Fisher Scientific, Pittsburgh, PA) and then collected into a 50-ml tube. They were stored at 4 °C before being counted within 2 weeks. If the egg samples could not be counted within 2 weeks, they were stored at −20 °C before being counted. Corn yield was determined by harvest from 6.7 m of the two central rows, and the grain yield was computed at 15.5% moisture.

In 1999, all plots were grown with the *H. glycines*-susceptible soybean ''Parker'' without additional fertilizer applied. Imazethapyr (Pursuit DG, American Cyanamid, Research Triangle Park, NC) at 0.07 kg/ha and trifluralin (Treflan HFP, Dow AgroSciences, Indianapolis, IN) at 0.84 kg/ha was used to control weeds. Soybean yield was determined from 6.1 m of the two central rows, and the grain yield was computed at 13.0% moisture.

Soybean yields and *H. glycines* egg densities were used in analysis of variance (ANOVA). Egg densities were transformed to $\log_{10}(x)$ values to improve homogeneity of variance. Unless otherwise stated, when the *F*-test was significant at $P < 0.05$, treatment mean comparisons were made with Fisher's protected least significant difference (LSD) test at the $P = 0.05$ level.

Experiment 2: In 1999, two additional field sites were located at Lamberton and Waseca for this study. Soybean was grown in 1998 at both sites. The soil at the Waseca site was a clay loam with 33% sand, 32% silt, 35% clay, 7.0% organic matter, and pH 8.0; the soil at the Lamberton site was a clay loam with 38% sand, 33% silt, 29% clay, 5.2% organic matter, and pH 7.3. The *H. glycines* populations were race 3 at both sites.

The experiment was a factorial design involving four trap-crop options and five trap-crop kill dates arranged in randomized complete blocks with six replicates. The four trap-crop options included *H. glycines*-resistant soybean ''Freeborn'' (with resistance derived from PI 88788), susceptible soybean Parker, pea ''Polar,'' and a control without any trap crop. The five trap-crop kill dates were 3, 4, 5, and 6 weeks after planting, as well as a no-kill treatment. Soybean was planted at a seeding rate of 494,000 seeds/ha, and pea was planted at a seeding rate of 1,480,000 seeds/ha. The soybean and pea were planted before planting DeKalb 493rr corn on 26 May 1999 at both sites. Trap-crop kill dates with glyphosate were June 16, June 24, June 30, and July 7 at Waseca and June 17, June 24, June 30, and June 9 at Lamberton. Nematode and corn yield measurements and other procedures were the same as used in Experiment 1, except in this experiment soybean yield in 2000 was not determined.

Results

Experiment 1: No significant effect of trap-crop treatments on the *H. glycines* population density was observed in Experiment 1 in 1998 (Table 1). Average Pi were 1,900 and 10,852 eggs/100 cm^3 soil at Waseca and Lamberton, respectively. These egg numbers represent moderate and high densities of *H. glycines* in the region. There was no significant reduction of egg densities at harvest compared with egg density at planting at the

TABLE 1. Population densities of *Heterodera glycines* in field plots grown with the nematode-resistant soybean "Pioneer 9234" as a trap crop in the corn year at two sites in Minnesota, 1998.

		Eggs/100 cm^3 soil							
		Waseca				Lamberton			
Treatment	Level of treatment	Pi[a]	Pm1[b]	Pm2[c]	Pf[d]	Pi	Pm1	Pm2	Pf
Seeding rate	0 seeds/ha	1,786	2,039	1,863	1,855	10,072	7,981	10,251	8,610
	124,000 seeds/ha	1,801	2,047	1,619	2,013	11,186	10,973	9,972	9,333
	247,000 seeds/ha	1,734	2,040	1,519	1,558	11,140	8,241	8,527	8,356
	494,000 seeds/ha	2,281	2,016	1,457	1,679	11,011	9,653	8,913	9,311
Kill time	3 wks after planting	2,228	1,997	1,824	2,106	11,130	9,377	10,141	9,059
	4 wks after planting	1,591	1,891	1,652	1,457	11,259	9,245	9,428	9,544
	5 wks after planting	1,981	2,364	1,495	1,652	11,247	8,925	9,371	8,250
	6 wks after planting	1,801	1,888	1,488	1,891	9,772	9,538	8,723	8,758
Mean		1,900	2,035	1,615	1,777	10,852	9,271	9,416	8,903
CV (%)		65	64	57	57	59	55	46	50

Data are the means of main effects with six replicates.
[a] Pi = egg density at planting.
[b] Pm1 = egg density 1 month after planting.
[c] Pm2 = egg density 2 months after planting.
[d] Pf = egg density at harvest.

Waseca site. At the Lamberton site, however, the egg density at harvest was 18% lower than the egg density at planting (Table 1). At both sites, no significant effect of planting soybean as a trap crop was observed on corn yield in 1998 or soybean yield in 1999 (Table 2).

Experiment 2: At the beginning of this experiment in 1999, both sites were infested with a high density of *H. glycines*, with 16,876 and 22,381 eggs/100 cm^3 soil at planting at Waseca and Lamberton, respectively (Table 3). On average, egg density was reduced by 62% ($P <$ 0.001) at harvest at Waseca and 43% ($P < 0.001$) at Lamberton compared with egg densities at planting (Table 4).

At the Waseca site, no difference in Pi, Pm1, and Pm2 was observed due to either trap crop or kill date, but Pf was influenced by trap crop (Table 3). At harvest, egg density was reduced if pea was grown for 5 or 6 weeks as compared with where no trap crop was grown (Table 3). Although the difference was not statistically significant, Pf was numerically lower where pea was grown for the whole season than where no trap crop was grown. Egg density at harvest where Freeborn was grown for 6 weeks was lower than where no trap crop was grown (Table 3). No difference in egg density was observed among other comparisons.

At the Lamberton site, variation in Pi for the subsequent treatments of the trap crops was large ($P = 0.04$). When the data were broken down by kill date, however, no difference in Pi was observed among the trap crops (Table 3). Egg density at harvest was lower where susceptible soybean Parker was grown for 5 weeks than where pea or no trap crop was grown (Table 3). No difference in egg density was observed among other treatments at any sampling occasion (Table 3).

As in Experiment 1, growing soybean as a trap crop did not affect corn yield at either site in 1999 (Table 5). At Waseca, however, corn yield was lower where pea was grown for 5 weeks or the whole season than where soybean or no trap crop was grown (Table 5). Corn yield was higher where pea was grown for only 3 and 4 weeks than where pea was grown for 5 weeks and for the whole season. It was unexpected that corn yield was higher where pea was grown for 6 weeks than where pea was grown for 5 weeks (Table 5). The effect of pea

TABLE 2. Effect of growing soybean as a trap crop in the corn year on corn and soybean yields at two sites in Minnesota.

		1998 corn yield (Mg/ha)		1999 soybean yield (Mg/ha)	
Treatment	Level of treatment	Waseca	Lamberton	Waseca	Lamberton
Seeding rate	0 seeds/ha	8.98	10.61	1.81	2.21
	124,000 seeds/ha	8.79	10.73	1.64	2.11
	247,000 seeds/ha	8.79	10.67	1.65	2.30
	494,000 seeds/ha	8.60	10.92	1.60	2.12
Kill date	3 wks after planting	8.85	10.48	1.58	2.20
	4 wks after planting	8.66	10.99	1.75	2.16
	5 wks after planting	8.91	10.80	1.65	2.18
	6 wks after planting	8.79	10.67	1.72	2.19
Mean		8.80	10.73	1.68	2.18
CV (%)		17	10	26	23

Data are the means of main effects with six replicates.

TABLE 3. Population densities of *Heterodera glycines* in field plots grown with soybean or pea as trap crops in the corn year at two sites in Minnesota, 1999.

	Kill date									
	Waseca					Lamberton				
Trap crop[a]	3 weeks	4 weeks	5 weeks	6 weeks	Not killed	3 weeks	4 weeks	5 weeks	6 weeks	Not killed
	Eggs/100 cm^3 soil at planting (Pi)									
No trap crop	16,933	13,784	18,827	18,000	16,013	21,800	20,600	21,867	19,033	18,833
Parker	16,787	18,953	14,660	17,133	18,300	18,633	27,200	25,600	21,400	20,400
Freeborn	16,433	17,760	18,667	15,234	14,000	23,520	19,200	24,167	20,120	19,833
Pea	17,640	16,277	16,493	18,900	16,400	24,350	28,667	22,000	25,333	25,533
	Eggs/100 cm^3 soil 1 month after planting (Pm1)									
No trap crop	13,710	10,812	11,841	13,467	14,100	16,867	14,400	17,067	16,760	11,433
Parker	10,842	15,215	12,367	10,827	14,133	15,333	14,940	12,967	13,200	13,333
Freeborn	13,333	11,400	12,752	14,474	8,958	16,100	16,600	16,733	17,167	19,733
Pea	12,960	11,279	10,075	10,208	10,746	20,733	15,333	15,150	17,533	19,120
	Eggs/100 cm^3 soil 2 months after planting (Pm2)									
No trap crop	11,360	9,293	7,347	11,103	9,487	14,900	18,180	18,667	16,157	10,933
Parker	12,233	6,833	6,733	7,127	8,223	17,420	15,910	15,460	17,850	14,383
Freeborn	9,070	9,617	10,400	8,867	7,073	15,650	13,283	17,287	14,817	12,896
Pea	9,663	10,217	7,330	6,717	8,570	17,910	13,633	13,500	19,323	19,733
	Eggs/100 cm^3 soil at harvest (Pf)									
No trap crop	8,327	7,387	6,108 a	9,990 a	7,848	14,210	12,867	13,703 a	15,667	13,803
Parker	6,382	7,052	7,685 ab	5,653 ab	6,087	12,870	12,942	7,803 b	10,980	10,730
Freeborn	7,013	5,458	6,595 ab	4,277 b	4,855	12,337	12,398	9,806 ab	9,499	12,357
Pea	8,032	5,277	4,238 b	4,845 b	4,262	15,017	17,535	12,183 a	14,390	13,070

Data are the means of six replicates. Values followed by the same lowercase letter(s) or without letter in a column or without letter in a row are not significantly different at $P = 0.05$ according to the Least Significant Difference test.
[a] Soybean cultivar Parker is susceptible, and Freeborn is resistant to *H. glycines.*

on corn yield, however, was not observed at the Lamberton site (Table 5).

DISCUSSION

In this study, we demonstrated that growing resistant or susceptible soybean in the corn year of a 2-year corn-soybean rotation to trap *H. glycines* was not effective for managing *H. glycines* in Minnesota. Although there was some reduction of Pf where Freeborn soybean was grown for 5 and 6 weeks at the Waseca site in 1999, the extent of the reduction was not adequate to be economically effective. As observed at the Waseca site in 1999, pea may have been more effective in lowering *H. glycines* population density than soybean as a trap crop in corn. This may have been due to better plant growth, higher plant populations, and poor *H. glycines* reproduction in peas compared with soybean. However, this effect was not observed at the Lamberton site. If *H. glycines* egg density was reduced from approximately 10,000 to 5,000 eggs/100 cm^3 soil, as observed with pea at Waseca in 1999, the predicted yield increase of susceptible soybean in the following year would be approximately 12% based on data obtained in a multiple-year evaluation of soybean cultivars in fields (Chen et al., 2001a). However, pea reduced corn yield by approximately 20% when the plants were maintained for more than 5 weeks. Hence, pea was not an economically effective trap crop in the corn year to manage *H. glycines*. Further study is needed to determine if pea can

TABLE 4. Average population density of *Heterodera glycines* in two field sites grown with soybean and peas as trap crops in the corn year in Minnesota, 1999.

	Eggs/100 cm^3 of soil				CV (%)			
Location	Pi[a]	Pm1[b]	Pm2[c]	Pf[d]	Pi	Pm1	Pm2	Pf
Waseca	16,876	12,140	8,863	6,369	38	38	43	48
Lamberton	22,381	15,997	15,920	12,708	34	42	40	48

[a] Pi = egg density at planting.
[b] Pm1 = egg density 1 month after planting.
[c] Pm2 = egg density 2 months after planting.
[d] Pf = egg density at harvest.

TABLE 5. Effect of growing soybean and pea as trap crops in the corn year on corn yields (Mg/ha) at two sites in Minnesota, 1999.

	Kill date				
Trap crop[a]	3 weeks	4 weeks	5 weeks	6 weeks	Not killed
			Waseca		
No trap crop	9.5	9.5	10.7 a	9.4	10.4 a
Parker	10.3	10.2	10.0 a	10.1	9.6 ab
Freeborn	9.9	10.4	9.6 ab	9.9	9.7 a
Pea	9.4 AB	10.4 A	8.2 cC	10.0 A	8.7 bBC
			Lamberton		
No trap crop	13.0	12.9	12.9	12.8	12.7
Parker	13.3	12.8	12.9	12.9	13.0
Freeborn	13.3	12.9	12.9	13.4	12.8
Pea	12.9	13.1	12.6	12.5	12.8

Data are the means of six replicates. Values followed by the same lowercase letter(s) or without letter in a column or by the same uppercase letter(s) in a row are not significantly different at $P = 0.05$ according to the Least Significant Difference test.
[a] Soybean cultivar Parker is susceptible, and Freeborn is resistant to *Heterodera glycines.*

be effectively used in crop rotation to manage *H. glycines.*

Soybean and pea plants can induce *H. glycines* egg hatch (Tefft and Bone, 1985; Chen, unpubl.). A possible reason for failure in growing these crops in corn to induce *H. glycines* hatch and reduce *H. glycines* egg density may have been that the population of soybean or pea was not large enough to release adequate amounts of root exudate for stimulating *H. glycines* hatch when the plants were destroyed at an early growth stage. If the soybean seeding rate increases, competition of soybean with corn would also increase. The highest seeding rate used in this study was 80 kg/ha, or approximately 6% of average soybean yield in Minnesota. If soybean seeding rate increases, the cost of seeds also would increase to where the economic benefit probably would be limited even if it could reduce *H. glycines* population density. Additionally, if the trap-crop soybean plants were maintained for more than 4 weeks, it is possible *H. glycines* could reproduce on the plants and increase population density. However, where susceptible soybean was grown for the whole season, the egg density did not increase compared with where no trap crop was grown. This was probably because the *H. glycines*-carrying capacity of the susceptible soybean growing in corn was low and could not support a higher nematode population.

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