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Impact of Crop Rotation and Bio-covers on Soybean Cyst Nematode

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Abstract

This research examined the effects of crop rotations and winter soil bio-covers on soybean cyst nematode (SCN) egg population density (EPD) under no-tillage. A field experiment with split-block treatments and four replications was conducted over three years with the whole-block treatments being rotations of corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr], and cotton (*Gossypium hirsutum* L.). Split-block treatments were bio-covers of winter wheat (*Triticum aestivum* L.), hairy vetch (*Vicia villosa* Roth), poultry litter, and fallow. Eggs were found in soybean-free sequences all four years, indicating potential residual viable SCN eggs in soil for seven years. Rotations with higher frequencies of soybean had significantly higher ($P \leq 0.01$) SCN EPD than others, with continuous soybean being greatest. We did not observe a significant difference due to bio-cover on SCN EPD.

Introduction

Soybean cyst nematodes (SCN) can cause up to 30% yield loss with no visible above-ground symptoms (16). Crop rotation has proven to be an effective management practice for some nematode species. It has been shown that rotation with non-host or SCN-resistant soybean cultivars reduces SCN population density and increases soybean yield in western Tennessee (8). However, SCN eggs encapsulated within a cyst go dormant during cooler temperatures, allowing them to survive harsh winter conditions (20,28). It has been observed that SCN eggs may survive up to 12 years in the absence of a host (1). Encysted eggs can remain viable in soil for more than three years in Mississippi with no host plant present (12), and over five years in Minnesota (18). Therefore, rotation designs should be tailored to site-specific conditions.

Winter covers, or bio-covers, reduce erosion and promote soil and water quality, and may affect nematode populations. Bio-covers that are alternative SCN host plants, such as hairy vetch (*Viciavillosa* Roth) (21), can increase nematode population density during winter (5). Non-host cover crops such as wheat (*Triticum aestivum* L.) can reduce SCN populations (12). Winter annuals present during winter fallow, including henbit (*Lamium amplexicaule* L.), chickweed (*Stellaria media* (L.) Vill.), and purple deadnettle (*Lamium purpureum* L.), can serve as SCN hosts (27). However, no indication of SCN reproduction was observed during three winter fallow periods on weeds or crimson clover (*Trifolium incarnatum* L.) in soybean production fields in western Tennessee (6). Poultry litter, used as a soil amendment, can suppress

nematode communities by encouraging the growth of parasitic fungi, such *Fusarium oxysporum* (12).

The effects of tillage on SCN reproduction have been mixed. In general, no-tillage appears to reduce populations of SCN (2,10,25) but lack of effect also has been reported (12,17). The objective of this study was to evaluate the effects of cropping sequence and winter bio-cover combinations on populations of SCN under no-tillage production.

Site Description

The field study was begun in 2002 at the Research and Education Center at Milan (RECM) in Milan, TN (35.54°N 88.44°W). Mean annual precipitation is 135 cm and mean annual temperature is 16°C. The soil type is a Loring B2 series: fine-silty, mixed, thermic Typic Fragiudalf.

The field site was planted in soybean in 1995 and 1996, cotton in 1997 and 1998, and soybean in 1999. In 2000, the entire site was planted in corn, and left fallow during the growing season prior to the experiment in 2001. Wheat was planted during each winter. The field was under no-tillage production for over 16 years prior to initiation of this experiment.

Experiment Design

The experiment was a split-block design with treatments arranged in randomized complete blocks. The whole plot treatments were crop rotations, which were strip-applied across the length of the field. Thirteen individual cropping rotations consisting of glyphosate-resistant corn, soybean, and cotton were planted (Table 1). Four bio-cover treatments, including hairy vetch, winter wheat, poultry litter, and fallow, were strip-applied as a sub-plot treatment perpendicular to crop sequence strips to give 52 sequence × bio-cover combinations applied to separate 6.1-m by 12.2-m subplots. Each treatment combination was replicated four times for a total of 208 plots. Cultivars planted were 'PM 1218 BG/RR' cotton, 'DKC 6410 RR' corn, and 'USG 744onRR' soybean, which has exhibited moderate resistance to races 3 and 14 of SCN (24). Cotton was planted on 102-cm rows while corn and soybean were planted on 76-cm rows.

Table 1. Cropping sequences planted over the four-year experimental period at the Research and Education Center at Milan, TN.

Crop sequence	Year			
	2002	2003	2004	2005
1	Cotton	Cotton	Cotton	Cotton
2	Corn	Corn	Corn	Corn
3	Soybean	Soybean	Soybean	Soybean
4	Soybean	Soybean	Soybean	Cotton
5	Corn	Soybean	Corn	Soybean
6	Soybean	Soybean	Soybean	Cotton
7	Soybean	Cotton	Corn	Soybean
8	Corn	Corn	Soybean	Cotton
9	Corn	Cotton	Soybean	Corn
10	Cotton	Soybean	Cotton	Corn
11	Cotton	Soybean	Corn	Cotton
12	Cotton	Corn	Cotton	Soybean
13	Cotton	Corn	Cotton	Corn

Fertilizer was applied as appropriate to each crop according to soil tests and the guidelines published in the Tennessee Agricultural Extension Service Guidelines to Crop Production, and litter was applied at the rate of 66.7 kg N/ha, assuming 50% bioavailability (26). Nutrient content of the poultry litter, vetch, wheat, and winter weeds (fallow) bio-covers were tested by A&L Analytical Laboratories Inc. (Memphis, TN). To determine nutrient content of vetch, wheat, and winter weeds, a 0.5-m by 1-m sample of the aboveground living material was taken just prior to spring glyphosate treatment. All bio-cover strips received the equivalent of 66.7 kg N/ha (NH_4NO_3) prior to planting. Pre-plant fertilizer application rates were reduced by the amount of nitrogen supplied by the vetch or other bio-covers, as appropriate. Corn plots received an additional 128.5 kg N/ha (liquid UAN 30%) and cotton received 33.35 kg N/ha (liquid UAN 30%) as side-dress treatments in late May or early June. Corn, soybean, and cotton plots were planted at the recommended seeding rates of 64,200 seeds/ha, 344,500 seed/ha, and 64,500 seed/ha, respectively (26).

Prior to planting, all emergent weeds were destroyed by either a paraquat (1,1-Dimethyl-4,4-bipyridinium) or glyphosate (N-phosphonomethyl-glycine) application in April. After seedling emergence, one or two applications of glyphosate were applied to the soybean and corn plots in either May or June of each year as needed for weed control. For the cotton plots, additional pesticide use was required and application dates ranged from June through September. Glyphosate and clethodim {(RS)-2-[2-[(E)-1-[(E)-3-chloroallyloxyimino] propyl]-5-[2-(ethylthio) propyl]-3-hydroxycyclohex-2-en-1-yl]-1-one} were used all four years. Def (S,S,S-Tributyl phosphorotrithioate) and Bidrin (Dimethyl phosphate of 3-Hydroxy-N,N-dimethyl-cis-crotonamide) were used as defoliants, and Pix (1,1-dimethylpiperidinium chloride) was applied to regulate cotton growth.

Sample Collection

SCN egg population density (EPD) was determined in 2003, 2004, and 2005, the final three years of the four-year cropping sequence. To determine SCN EPD, a composite sample of twelve soil cores (2.5 cm in diameter $\times$ 15 cm deep) was collected from the within- and between-row sections of each plot. Samples were collected approximately three weeks prior to spring bio-cover burndown during the third week of March. Cysts of SCN were extracted from the soil using a semi-automatic elutriator and eggs liberated and enumerated following the methodology of Niblack et al. (15). SCN egg population densities were rank transformed to correct for non-normality prior to analysis of variance with SAS proc mixed (22). Mean separation was performed using Fisher's LSD ($\alpha < 0.05$) (23). Original means are reported for interpretation.

Effect of Cropping Sequence

Mean pre-plant SCN EPD over all treatments ranged from 146 ± 4 eggs per 100 cm^3 of soil in 2004 to 195 ± 3 eggs per 100 cm^3 in 2005 (Fig 1). SCN infection and development is inhibited in soil with high moisture content (29). The late spring and fall are typically high in precipitation at Milan, TN, but in 2005, June, July, and September were below average in precipitation, with July and September receiving less than 25% of the historical average precipitation (13). Temperatures in March, April, May, June, and July of 2005 were higher than historical averages, which may have stimulated an early egg hatch and rapid development that year (1).

Fig. 1. Changes in soybean cyst nematode (SCN) at the 0- to 15-cm depth over time (2004-2006) at the Research & Education Center at Milan, TN, by crop sequence (Ct = cotton, Cr = corn, S = soybean) averaged across bio-covers (top); and by bio-cover averaged across crop sequence (bottom). Error bars denote 95% confidence interval.

Cropping rotation had a highly significant ($P < 0.01$) effect on SCN EPD for each of the three years (Table 2). Mean SCN population density was typically higher ($P \leq 0.05$) in rotations consisting of higher frequencies of soybeans. Additionally, rotations in which the previous year's crop was soybean had higher mean SCN egg densities than those planted in cotton or corn. This result indicates that SCN was able to infect and reproduce on the soybean variety 'USG 744onRR,' although this variety is moderately resistant to races 3 and 14 (25). Higher SCN egg densities occurred consistently throughout the 4-year sequence in the continuous soybean treatment. The highest density was 927 ± 582 eggs per 100 cm³ of soil after two years of the soybean crop (Fig. 1). SCN egg densities did not differ in subsequent years (672 ± 313 eggs per 100 cm³ and 909 ± 737 eggs per 100 cm³ of soil in 2005 and 2006, respectively). Assuming an average of 200 eggs per cyst (15), these egg densities are equivalent to approximately 3 to 4 cysts per 100 cm³ of soil, well below the University of Tennessee economic threshold value of 20 cysts per 100 cm³ of soil (14).

SCN EPD dropped after one year of rotation with a non-host crop in all treatments. However, some carryover between years was observed, with rotations that had two years of soybeans in the four-year sequence having higher SCN than rotations with one year of soybean. For example, soybean (S)-cotton (Ct)-(S)-(Ct) had higher mean SCN EPD in 2005 (549 per 100 cm³) than corn (Cr)-Ct-S-Cr (132 per 100 cm³) and Ct-S-Ct-Cr (81 per 100 cm³) (Table 2). Chen et al. (4) found similar results where rotation with a soybean cultivar with resistance to SCN in addition to use of a non-host reduced the population density. These results differ from work reported in Minnesota (11) and Missouri (9) in which one year of non-host crop rotation and winter fallow did not consistently reduce SCN survival. The discrepancy may be due to different climatic conditions, as regions with warmer winters are less favorable for SCN survival than those with cooler winters (20).

Table 2. Means and 95% confidence intervals (CI) for soybean cyst nematode egg population densities (per 100 cm³ of soil) for three years of cropping rotations under no-tillage at the Research and Education Center at Milan, TN.

Crop sequence	Year					
	2004		2005		2006	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Ct-Ct-Ct-Ct ^x	6ef ^y	11	84bc	52	12de	10
Cr-Cr-Cr-Cr	3ef	6	105bc	43	39cde	35
S-S-S-S	927a	582	672a	313	909a	737
S-S-Cr-Ct	4299ab	325	222ab	75	78bcde	78
Cr-S-Cr-S	21de	17	138bc	65	132bc	174
S-Ct-S-Ct	114cd	100	549a	234	114bcd	89
S-Ct-Cr-S	204bcd	166	153bc	85	318b	217
Cr-Cr-S-Ct	0f	0	93cd	47	42bcde	35
Cr-Ct-S-Cr	3ef	6	132bc	62	63cde	102
Ct-S-Ct-Cr	111abc	83	81cd	61	36cde	31
Ct-S-Cr-Ct	69def	113	51d	29	12e	13
Ct-Cr-Ct-S	3ef	6	138bc	58	30bcde	20
Ct-Cr-Ct-Cr	3ef	6	117cd	59	33cde	26
Average ^z	146	109	195	91	140	121

^x Ct = cotton, Cr = corn, S = soybean. Cropping rotations were started in 2003.

^y Values in a column followed by a common letter are not significantly different; Fisher's protected least significant difference at $P \leq 0.05$ was performed on rank transformed data (*not shown*).

^z Average of all rotations at RECM, $n = 208$; each mean is an average across all bio-covers.

Residual SCN occurred in all plots throughout the experiment, even when soybean was absent in the rotational sequence. For example, continuous cotton Cr-Ct-Cr-Ct rotation and continuous corn had mean SCN egg population densities greater than zero in all three years. SCN eggs found in rotations without soybean do not appear to be experimental error for five reasons. First, under controlled conditions, SCN has been shown to survive more than 12 years at soils maintained near field capacity (29). Second, the site was planted in soybean three, six, and nine years prior to initiation of the experiment, and may have developed a well established SCN population. SCN cysts are known to persist in similar environments for over four years. SCN egg dormancy can be dependent on climate conditions, root exudates, and time (28). Third, eggs were found consistently in most bio-covers and treatment plots with entirely non-host cropping rotations each year. Fourth, those plots exhibiting SCN infestation in any single year continued to have elevated egg densities throughout the course of the experiment. Finally, there may have been some reproduction on weeds that grew on the plots over the winter. Although no reproduction was seen on winter weeds by Donald et al. (6), given favorable weather conditions, SCN can reproduce on chickweed (*Stellaria media*) and henbit (*Lamium amplexicaule*) (21), which grew on soybean sites during the non-growing period. Although soybean planting frequency is typically responsible for elevated SCN counts, these results indicate that reproduction in the bio-cover may play a role in SCN population density.

Role of Bio-Covers

Although variability obscured any possible treatment significance, there were some trends among the mean SCN population densities under winter bio-

covers (Fig. 2). Fallow, poultry litter, and wheat SCN population densities were lower than the average SCN density two out of the three years (Table 3). This observation in the fallow bio-cover is in agreement with research performed by Donald et al. (6) who found no SCN reproduction on weeds in winter fallowed soybean fields in southwestern Tennessee.

Fig. 2. Changes in soybean cyst nematode (SCN) 0- to 15-cm over time (2004-2006) at the Research & Education Center at Milan, TN, by crop sequence (Ct = cotton, Cr = corn, S = soybean) averaged across bio-covers in 2004 (A), 2005 (B), and 2006 (C) and by bio-cover averaged across crop sequence in 2004 (D), 2005 (E), and 2006 (F). Error bars denote 95% confidence interval ($\pm 2 \times \text{std. error}$).

Table 3. Means and 95% confidence intervals (CI) for soybean cyst nematode egg population densities (per 100 cm³ of soil) for three years of bio-covers under no-tillage at the Research and Education Center at Milan, TN.

Bio-cover	Year					
	2004		2005		2006	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Fallow	188a ^x	167	169a	74	105a	74
Litter	36a	24	198a	66	103a	99
Vetch	184a	137	224a	115	162a	118
Wheat	175a	135	189a	68	189a	220
Average ^y	146	116	195	81	140	128

^x Values in a column followed by a common letter are not significantly different; Fisher's protected least significant difference at $P \leq 0.05$ was performed on rank transformed data (*not shown*).

^y Average of all rotations at RECM, n = 208; each mean is an average across all bio-covers of that crop rotation.

Though others have found that wheat residue can have a suppressive effect on SCN (7), no significant wheat bio-cover effect was observed in this study. Across all crop rotations, SCN EPD under poultry litter was lowest of all bio-covers in two of the three years, ranging from 36 ± 2 eggs per 100 cm³ to 103 ± 7 eggs per 100 cm³ in 2004 and 2006, respectively (Table 3). Others have found that poultry litter can promote the growth of bacteria and fungi (19), and may increase the population of nematophagous fungi, such as *Fusarium solani*, *F. oxysporum*, *Paecilomyces lilacinus*, and *Verticillium chlamydosporium*, which parasitize SCN (3). This parasitism may explain the slightly lower mean SCN egg densities observed in this study under poultry litter.

Vetch supported higher mean SCN densities in all three years. The highest SCN EPD across all bio-covers and years, 224 ± 8 eggs per 100 cm³, was seen under vetch in 2004, supporting the findings of Riggs (21), who found that hairy vetch can serve as a host to SCN under proper conditions. During the historically warm winter of 2004-2005, SCN egg densities were highest in continuous soybean with vetch bio-cover (1068 ± 108 eggs per 100 cm³).

Conclusions

In spring 2006, SCN eggs were found in plots that had not been planted with soybean for seven years indicating that even with a low level of SCN, the nematode cannot be eliminated from infested soil in this length of time. SCN was able to establish and maintain an infective population on the cultivar 'USG 7440nRR,' which is rated as moderately resistant to SCN races 3 and 14. Likely due to this resistance, EPD remained well below the economic threshold throughout the experiment. Rotating SCN resistant soybean with non-host agronomic crops can reduce SCN EPD, with as little as one year being enough to reduce SCN density dramatically. These effects were cumulative, with EPD declining with decreasing frequency of soybean in four year crop rotations. Mean EPD was generally lowest under the poultry litter bio-cover and highest under hairy vetch, with wheat and fallow being intermediate.

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