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Efficacy of Cotton Root Destruction and Winter Cover Crops for Suppression of *Hoplolaimus columbus*[1]

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Abstract: The efficacy of rye (*Secale cereale*) and wheat (*Triticum aestivum*) winter cover crops and cotton stalk and root destruction (i.e., pulling them up) were evaluated in field tests during two growing seasons for *Hoplolaimus columbus* management in cotton. The effect of removing debris from the field following root destruction also was evaluated. Wheat and rye produced similar amounts of biomass, and both crops produced more biomass ($P \leq 0.05$) following cotton root destruction. Cover crops did not suppress *H. columbus* population levels or increase subsequent cotton yields. Cotton root destruction did not affect cotton stand or plant height the following year. Cotton root destruction lowered ($P \leq 0.05$) *H. columbus* population levels at planting in 1996 but not in 1997, but cotton yield was not increased by root destruction in either year. Removing debris following root destruction did not lower *H. columbus* levels compared to leaving debris on the soil surface. This study suggests that a rye or wheat cover crop or cotton root destruction following harvest is ineffective for *H. columbus* management in cotton.

Key words: Columbia lance nematode, cotton, cover crop, *Gossypium hirsutum, Hoplolaimus columbus,* nematode management, root destruction, rye, *Secale cereale, Triticum aestivum,* wheat.

The Columbia lance nematode, *Hoplolaimus columbus* Sher., causes significant yield loss and economic damage to cotton and soybean in parts of Georgia, South Carolina, and North Carolina (Baird et al., 1996; Ferris and Ferris, 1998; Kraus-Schmidt and Lewis, 1979; Noe et al., 1991; Starr, 1998). Peanut (*Arachis hypogaea* L.) is an effective rotation crop for *H. columbus* management in cotton, but peanut hectarage is restricted by a quota system and most cotton farmers in Georgia cannot grow enough hectares of peanuts to use it as a rotation crop. Corn (*Zea mays* L.) and soybean (*Glycines max* L.) also are potential rotation crops for cotton in Georgia, but both are hosts for *H. columbus* (Fassuliotis, 1974). Consequently, because cotton has the greatest potential to be profitable, many Georgia farmers grow consecutive cotton crops without rotation and rely on nematicides for management of *H. columbus.* There is a need for management options that can be used to supplement nematicide use in continuous cotton.

Approximately 120,000 ha each of wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) are grown each year in Georgia, but only 85% of the wheat and 20% of the rye are harvested for grain (Bass and Messer, 2000). The remaining hectarage is grown as a winter cover crop and is typically killed by herbicide treatment or tillage prior to planting a summer crop such as cotton. Wheat is a host for *H. columbus* (Fassuliotis, 1974), but the host status of rye is not well documented. Rye is reported to release compounds toxic to nematodes and provide nematode suppression when plowed under and allowed to decay (Patrick et al., 1965).

Implements used primarily in minimum-tillage cotton production are available (Arizona Drip Systems, Inc., Coolidge, AZ, and Amadas Industries, Suffolk, NC) to destroy cotton root systems following harvest. Plowing or pulling up stalks following harvest is a recommended practice for tobacco growers (Johnson, 1989) to reduce *Meloidogyne* spp. population levels by exposing roots containing nematodes and egg masses to above-ground temperature and moisture fluctuations (Sasser and Carter, 1982). Steele (1972) documented that nematodes can continue to mature and reproduce on post-harvest root debris. Root destruction following harvest was first proposed by Bessey (1911) and is effective primarily with crops that have a perennial growth habit (Trivedi and Barker, 1986), such as cotton. Both vermiform and egg stages of *H. columbus,* a mi-

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gratory endoparasite, can be found inside cotton roots (Heald et al., 1981; Lewis et al., 1976; Lewis and Fassuliotis, 1982; Starr, 1998). It has been suggested (Lewis and Fassuliotis, 1982) that exposing cotton roots to aboveground conditions reduces *H. columbus* population levels.

This study was conducted to determine if either cotton root destruction following harvest or a winter cover crop of wheat or rye affected *H. columbus* population levels and subsequent yield of cotton. The effect of removing cotton stalk and root debris from the field following cotton root destruction also was evaluated.

Materials and Methods

Plots were established in a non-irrigated field at the University of Georgia Southeast Branch Experiment Station in Midville, Georgia, with a natural infestation of *H. columbus.* The soil was characterized as a Dothan sandy loam (fine loamy, siliceous, thermic, plinthic paleudults; 69% sand, 13% silt, 18% clay).

A factorial arrangement of treatments was used in this study. One factor included either fallow, a winter cover crop of rye, or a winter cover crop of wheat in combination with nematicide application on the subsequent cotton crop. A second factor in the experiment was either leaving cotton stalks and roots in place after harvest or stalk and root destruction (i.e., pulling them up) immediately after harvest. Winter fallow followed by cotton without nematicide application, both with and without stalk and root destruction, served as controls. A completely randomized design with four replications of each treatment combination was used. Individual plots were 18 m long and 8 rows wide with a 97-cm row spacing.

Wheat (cv. Coker 9835) and rye (cv. Wrens Abruzzi) both were planted on 21 November 1995 and 5 Dec 1996. Seeding rates were 67.2 kg/ha and 62.8 kg/ha for wheat and rye, respectively, each year, and no fertilizer was applied either year to the cover crops. On 15 April 1996 and 7 April 1997, the cover crops were sprayed with paraquat at 0.70 kg a.i./ha and turned under with a moldboard plow 4 days later. Cotton (cv. Deltapine 5415) was planted on 14 May in both 1996 and 1997 and harvested on 15 November and 20 November in 1996 and 1997, respectively. Cotton plots that received nematicide application were treated with aldicarb (Temik 15G, Aventis Corp., Research Triangle Park, NC) at 0.59 kg a.i./ha at planting. All cotton plots were oversprayed as necessary with acephate (Orthene 75, Valent USA Corp., Walnut Creek, CA) at 0.20 kg a.i./ha for thrips control. Fertilization, weed control, and additional insect control were performed according to Georgia Cooperative Extension Service recommendations for cotton.

Cotton roots were destroyed mechanically in appropriate plots following harvest using a device consisting of two spinning automobile-sized tires. The tires were oriented nearly perpendicular to the rows, with one tire on each side of the row. The tires, which lightly touched directly over the row, rotated in opposite directions so that when a cotton stalk passed between them, it was pulled out of the ground. This method did not destroy all root tissue because it primarily removed the larger roots, leaving some smaller roots in the soil.

Soil samples for nematode assays were collected prior to planting the cover crop, prior to paraquat application to cover crops, prior to cotton planting, at midseason (22 August 1996 and 11 July 1997), and at cotton harvest in both years of this study. Nematodes were extracted by centrifugal flotation (Jenkins, 1964) from 100 cm^3 of soil. Cotton yield data were collected at harvest in 1996 and 1997. The number of cotton plants per 3 m of row and mean plant height were recorded on 11 July 1997. Dry weight of the wheat and rye cover crops was determined prior to being treated with paraquat on 4 April 1996 by destructively sampling, drying, and weighing the biomass from 1 m^2 per plot.

In a separate experiment at the same location, 4-row plots (97-cm row spacing) 7.6 m long were used to evaluate the effect of removing cotton stalk and root debris from

TABLE 1. Biomass of wheat and rye cover crops with and without cotton root destruction in 1997.

	Cover crop biomass: dry weight (g/m^2)[a]		
	Cotton roots		
Cover crop	Destroyed	Not destroyed	Mean[b]
Wheat	51.8	23.7	39.7a
Rye	69.5	44.5	57.0a
Mean[c]	60.6a	35.6b	

[a] Samples collected on 23 April 1997.

[b] Cover crop means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

[c] Roots destroyed or not destroyed means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

the field following root destruction. All plots were identical except for the two treatments being evaluated: leaving the debris on the surface of the plot and removing the debris by hand from the field. Plots were arranged in a randomized complete-block design with six replications. Cotton was planted following winter fallow. Soil samples for nematode assay were collected on 21 November 1995 and 14 May 1996.

Lint yield (kg lint/ha) was calculated as 38% of seed cotton yield. Data were analyzed as a factorial arrangement of treatments in a completely randomized design. With no statistical interaction between factors, Fisher's protected $LSD_{(0.05)}$ was used for multiple comparison of means for each factor by averaging each level of one factor across all levels of the other factor.

RESULTS AND DISCUSSION

Prior to paraquat application in 1997, wheat and rye produced similar amounts of dry matter regardless of whether cotton roots were destroyed or left intact (Table 1). In plots where cotton roots were destroyed following harvest in 1996, both wheat and rye produced more biomass than where roots were not destroyed. Cover crop dry matter was not measured in 1996.

Cotton root destruction after the previous crop did not have a significant effect on cotton plant stand in the subsequent season (plants/3 m of row) or plant height in 1997 (Table 2). Cotton plus aldicarb following wheat, rye, or winter fallow had higher plant stands and plant height than cotton that did not receive aldicarb. Although not measured in this test, reduced stands and plant height in the absence of aldicarb were likely due to damage from thrips because of less efficacious control from acephate applications. Cotton plus aldicarb produced similar plant stands and heights after wheat, rye, or winter fallow.

Cotton root destruction reduced *H. columbus* population levels at planting in 1996 (Table 3), but in 1997 *H. columbus* population levels at planting were numerically lower but not statistically different (Table 4). Root destruction did not affect yield or nematode population levels in the soil at midseason in either 1996 or 1997. Davis and Noe (2000) documented that population levels of *H. columbus* in the soil were suffi-

TABLE 2. The effect of cover crop and nematicide combinations with and without cotton root destruction on cotton stand and plant height in 1997.

	Cotton plants per 3 m of row			Plant height (cm)[a]		
Cover crop/ nematicide	Roots destroyed	Not destroyed	Mean[b]	Roots destroyed	Not destroyed	Mean
None/None	17	19	18.1b	19	18	18.4b
None/Aldicarb (0.59 kg a.i./ha)	37	37	36.5a	37	42	39.7a
Wheat (1 bu/A)/Aldicarb (0.59 kg a.i./ha)	36	34	35.0a	41	32	36.5a
Rye (1 bu/A)/Aldicarb (0.59 kg a.i./ha)	32	33	32.3a	39	36	37.5a
Mean[c]	30.3a	30.6a		34.1[a]	31.9a	

[a] Based on mean height of 10 plants per plot on 11 Jul 1997.

[b] Cover crop/nematicide means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

[c] Roots destroyed or not destroyed means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

TABLE 3. The effect of cover crop and nematicide combinations with and without cotton root destruction on cotton yield and *Hoplolaimus columbus* population levels at selected points during 1996.

	H. columbus population levels per 100 cm^3 soil[a]								
	14 May			22 August			Yield (kg lint/ha)		
Cover crop/ nematicide	Roots destroyed	Not destroyed	Mean[b]	Roots destroyed	Not destroyed	Mean	Roots destroyed	Not destroyed	Mean
None/None	87	168	127a	192	162	177b	545	399	472a
None/Aldicarb	73	144	109a	287	240	264ab	732	561	659a
Wheat/Aldicarb	117	147	132a	291	250	270a	634	561	598a
Rye/Aldicarb	45	137	91a	338	244	291a	512	616	572a
Mean[c]	80b	149a		277a	224a		617a	542a	

[a] Wheat and rye were sprayed with paraquat on 15 April, plots were planted on 14 May, and plots were harvested on 15 November.

[b] Cover crop/nematicide means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

[c] Roots destroyed or not destroyed means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

cient for comparing treatments at a given sampling date. Removing debris after cotton root destruction did not significantly reduce *H. columbus* population levels, though levels were reduced numerically from 378/100 cm^3 in plots where debris was not removed to 249/100 cm^3 in plots where debris was removed.

There was a trend toward a reduction in *H. columbus* levels at planting the season following cotton root destruction. Davis and Noe (2000) found that nearly 100% of the vermiform *H. columbus* population was outside of cotton root tissue at harvest, but they did not consider eggs in the roots. *Hoplolaimus columbus* lays eggs in both the roots and the soil (Heald et al., 1981; Fassuliotis, 1975). The consistent numerical reduction in *H. columbus* population levels at planting after cotton root destruction indicates that a significant number of eggs inside cotton roots at harvest may be killed when roots are destroyed.

Neither wheat nor rye had an effect on *H. columbus* population levels or subsequent cotton yield in 1996 or 1997 compared to winter fallow (Tables 3,4). There was no indication that either wheat or rye served as hosts for *H. columbus* in this study, though reproduction could have been limited by soil temperature. To minimize input costs, cover crops in Georgia that will not be har-

TABLE 4. The effect of cover crop and nematicide combinations with and without cotton root destruction on cotton yield and *Hoplolaimus columbus* population levels during 1997.

	H. columbus population levels per 100 cm^3 soil[a]								
	14 May			11 July			Yield (kg lint/ha)		
Cover crop/ nematicide	Roots destroyed	Not destroyed	Mean[b]	Roots destroyed	Not destroyed	Mean	Roots destroyed	Not destroyed	Mean
None/None	111	100	106a	110	43	76a	495	532	508b
None/Aldicarb	113	131	122a	91	73	82a	762	837	799a
Wheat/Aldicarb	83	87	85a	69	55	62a	736	781	755a
Rye/Aldicarb	55	184	119a	51	47	49a	753	775	764a
Mean[c]	90a	126a		80a	54a		687a	759a	

[a] Wheat and rye were sprayed with paraquat on 15 April, plots were planted on 14 May, and plots were harvested on 15 November.

[b] Cover crop/nematicide means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

[c] Roots destroyed or not destroyed means followed by the same letter are not significantly different ($LSD_{0.05}$). A significant interaction between factors did not occur in this test.

vested are typically seeded at a relatively low rate and are not fertilized. The unfertilized cover crops in this study produced less biomass than would likely be expected from a fertilized cover crop. Rye has been reported in some studies to effectively suppress plant-parasitic nematodes (Guertal et al., 1998; Minton and Parker, 1987), but other studies report no suppression (Johnson et al., 1998; McKeown et al., 1998; McSorley and Gallaher, 1994; Minton, 1992; Minton and Bondari, 1994; Viaene and Abawi, 1998). Patrick et al. (1965) showed that nematode mortality was linearly related to the concentration of the toxic products of rye decomposition. Nematode suppression and subsequent cotton yield increases in our study might have been improved had the cover crops produced more biomass resulting in higher concentrations of toxic decomposition products. It also is possible that applying paraquat to cover crops prior to incorporation reduced their effect in the study reported herein. Butyric acid is the compound most likely responsible for nematode mortality in decomposing rye, but it is only nematicidal when pH ranges from 4.0 to 5.3 (Sayre et al., 1965). Though not measured during the study, soil pH in the field used in this study has subsequently ranged between 5.7 and 6.1, which may also offer a possible explanation of why rye had no significant effect on *H. columbus* population levels.

Cotton that received aldicarb following rye, wheat, or winter fallow had similar yields, and *H. columbus* population levels at midseason were similar in 1996 and 1997 (Tables 3,4). Cotton that did not receive aldicarb had lower *H. columbus* population levels at midseason in 1996 than plots that received aldicarb, and yield was lower in 1997 in plots that did not receive aldicarb. Plant stand and midseason plant height (Table 2) also were reduced in the absence of aldicarb, possibly resulting in reduced root biomass that supported fewer nematodes but also suppressed yield.

This study indicates that an unfertilized wheat or rye cover crop seeded at a low rate did not increase cotton plant stand, increase cotton height, reduce *H. columbus* population levels, or increase subsequent cotton yields when combined with a nematicide. Seeding the cover crop at a higher rate or fertilizing the cover crop would likely increase biomass and might result in *H. columbus* population suppression, but those practices cannot be recommended where a nematicide is used without additional data. Cotton root destruction lowered *H. columbus* population levels at planting in 1996, but yields were not increased by root destruction in either year. Consequently, root destruction cannot be recommended for *H. columbus* suppression.

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