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Effects of Potato-Cotton Cropping Systems and Nematicides on Plant-Parasitic Nematodes and Crop Yields[1]

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Abstract: *Belonolaimus longicaudatus* has been reported as damaging both potato (*Solanum tuberosum*) and cotton (*Gossypium hirsutum*). These crops are not normally grown in cropping systems together in areas where the soil is infested with *B. longicaudatus.* During the 1990s cotton was grown in a potato production region that was a suitable habitat for *B. longicaudatus.* It was not known how integrating the production of these two crops by rotation or double-cropping would affect the population densities of *B. longicaudatus,* other plant-parasitic nematodes common in the region, or crop yields. A 3-year field study evaluated the viability of both crops in monocropping, rotation, and double-cropping systems. Viability was evaluated using effects on population densities of plant-parasitic nematodes and yields. Rotation of cotton with potato was found to decrease population densities of *B. longicaudatus* and *Meloidogyne incognita* in comparison with continuous potato. Population densities of *B. longicaudatus* following double-cropping were greater than following continuous cotton. Yields of both potato and cotton in rotation were equivalent to either crop in monocropping. Yields of both crops were lower following double-cropping when nematicides were not used.

Key words: *Belonolaimus longicaudatus,* cotton, crop rotation, cropping system, double-cropping, *Gossypium hirsutum, Meloidogyne incognita,* nematode, potato, root-knot nematode, *Solanum tuberosum,* sting nematode.

The number of hectares in Florida planted to cotton (*Gossypium hirsutum* L.) increased during the 1990s (Anonymous, 1999), expanding into some regions where cotton was not traditionally grown. One such region is northeast Florida, where potato (*Solanum tuberosum* L.) has been produced for the last 100 years (Weingartner et al., 1993). *Belonolaimus longicaudatus* Rau (sting nematode) is well adapted to the northeast Florida area and is commonly found in agricultural fields (Nguyen and Smart, 1975; Weingartner et al., 1993). Both cotton (Crow et al., 2000a; Graham and Holdeman, 1953) and potato (Crow et al., 2000b) are severely affected by *B. longicaudatus.*

Besides *B. longicaudatus,* other nematodes considered important to potato production in the region are root-knot nematodes (*Meloidogyne incognita*) and the stubby root nematodes (*Paratrichodorus minor* and *Trichodorus* spp.); the latter transmit the tobacco rattle virus. Other plant-parasitic nematodes commonly identified from growers' fields in the area are *Dolichodorus* spp., *Mesocriconema* spp., *Helicotylenchus* spp., *Hemicycliophora* spp., *Hoplolaimus* spp., *Pratylenchus* spp., and *Tylenchorhynchus* spp. All of the commercial potato fields in northeast Florida are treated with nematicides for management of plant-parasitic nematodes and associated disease complexes (Weingartner and Shumaker, 1983).

Crop rotation has been shown to affect population densities of plant-parasitic nematodes (Noe, 1998; Rodríguez-Kábana and Canullo, 1992). These effects may reduce or exacerbate nematode problems depending on the crops and nematode species present in the system. Cotton and potato are not commonly grown in a crop production sequence, so it was not known how rotation or double-cropping of these crops would affect population densities of plant-parasitic nematodes in the system. The objectives of this

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study were to evaluate the viability of different potato and cotton cropping sequences based on population densities of plant-parasitic nematodes and crop yields.

Materials and Methods

A field study was conducted from 1996 to 1998 at the University of Florida Agricultural Research and Education Center, Yelvington Farm near Hastings, Florida. The site, located in a potato production region, has been used primarily for potato research during the past 40 years. Soil type was an Ellzey fine sand (sandy, silicaceous, hyperthermic Arenic Ochraqualf): 95% sand, 2% silt, 3% clay; <1% organic matter; pH 6.5 to 7.0. The site was naturally infested by *B. longicaudatus, Mesocriconema* sp., *Dolichodorus heterocephalus, Hemicycliophora* sp., *M. incognita* race 1, *P. minor, Pratylenchus brachyurus, P. zeae,* and *Tylenchorhynchus* sp. Bed construction and irrigation were consistent with standard potato production practices for the area (Campbell et al., 1978; Rogers et al., 1975).

The experimental design was a split-plot, with cropping systems as whole-plots and nematicide treatments as subplots. The field design included five beds, with each bed being a block. Five cropping treatments and three nematicide treatments were tested. Plots were 9 m long and 4 m wide, with 102 cm between rows. Three meters of clean fallow were maintained as an alley between plots in the same rows. Two bare-fallow rows were maintained between plots in adjacent rows. All data were collected from the center two rows of each plot. All statistical analysis was performed using the SAS software program (SAS Institute, Cary, NC).

Cropping systems were: (i) winter-spring potato followed by a cover crop of sorghum-sudangrass hybrid (*Sorghum bicolor* (L.) Moench × *S. arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.), representing the standard cropping system for potato in the region (Weingartner et al., 1993); (ii) monocropped cotton grown during the summer; (iii) winter-spring potato double-cropped with summer cotton; (iv) cotton and potato in a 1-year rotation; and (v) 2 years of summer cotton followed by winter-spring potato and summer sorghum-sudangrass in the third year. Nematicide treatments were aldicarb, 1,3-dichloropropene (1,3-D), and untreated.

Aldicarb was applied in a 25-cm-wide band at 3.4 kg a.i./ha (34 g/100 m of row) directly over potato seed pieces and incorporated lightly as the beds were closed. Prior to planting cotton, the rows were flattened with a stalk chopper and aldicarb was applied in a 25-cm-wide band at 1.7 kg a.i./ha (17 g/100 m of row) on top of the flattened rows. The aldicarb was incorporated with the soil as the rows were reshaped for planting. 1,3-Dichloropropene (1,3-D) was injected 25 to 30 cm deep into the soil at 56 liters/ha (570 ml/100 m of row) by a single chisel per row 3 weeks before planting either crop.

For the double-cropped treatments, nematicides were applied prior to planting to both crops. Untreated plots received no nematicide on either crop. In plots where potato was treated with aldicarb, the cotton also was treated with aldicarb. In plots where potato was fumigated with 1,3-D, the cotton was treated with aldicarb.

Potato was planted in February to early March each year (Table 1). 'Atlantic' potato seed pieces were hand-placed 20 cm apart. Potato tubers were mechanically harvested in May to early June with a single-row harvester, graded, and weighed. Analysis was limited to tubers ≥3.81-cm diam.

All cotton, except the double-cropped cotton, was planted in late April 1996 and harvested in mid-October (Table 1). The double-cropped cotton was planted in early June 1996, following the potato harvest, and harvested in early December (Table 1). All cotton was planted in late May and harvested in early November 1997, and planted in late June and harvested in early December 1998 (Table 1).

The cotton cultivar DPL 50 was grown in 1996. Variety trials ongoing at the time showed that this variety was unsuited to local conditions (D. Colvin, unpubl. data). Thereafter, in 1997 and 1998, the cultivar DPL

TABLE 1. Planting and harvest dates for crops grown in the cropping systems study conducted at the Yelvington Farm near Hastings, Florida, 1996 to 1998.

	1996		1997		1998	
Crop	Plant	Harvest	Plant	Harvest	Plant	Harvest
Potato	4 March	6 June	10 Feb	14 May	27 Feb	8 June
Monocropped cotton	26 April	22 Oct	22 May	17 Oct	29 June	9 Dec
Double-cropped cotton	13 June	11 Dec	22 May	17 Oct	29 June	9 Dec
Sorghum-sudangrass	13 June	22 Oct	22 May	7 Oct	29 June	26 Oct

5415 was used. Cotton seed was mechanically planted, and seedlings were thinned to 15-cm spacing following emergence. Cotton was harvested with a single-row mechanical harvester, and weight of seed cotton yield was recorded.

Nematode data were collected by taking 12 soil cores (2.5-cm-diam. × 20 cm deep) from the two center rows of each plot. The 12 cores were composited to form a single sample. Nematodes were extracted from a 130-cm^3 subsample using the centrifugal-flotation method (Jenkins, 1964) modified by doubling the sucrose concentration in the solution. Following extraction, individual genera of plant-parasitic nematodes were counted with an inverted light microscope at ×32 magnification.

The nematode samples collected in January of each year represented the initial population density (Pi) at the beginning of the potato season. Data from these nematode samples were used to evaluate the effects of the previous cropping systems on the current potato crop. Nematode counts were subjected to analysis using the general linear model procedure for a split-plot design, and the means were separated according to Duncan's multiple-range test (Ott, 1993). The block × whole-plot interaction was used as the error term for the whole-plot treatments. Nematicide treatment means within the same cropping system were subjected to analysis using the general linear model procedure, and the means were compared using Duncan's multiple-range test (Ott, 1993).

Some cropping treatments were the same for the first and second years of the study. For instance, the monocropped cotton treatment and two treatments with potato and cotton in rotation all had monocropped cotton during the first year. The monocropped cotton treatment and potato following 2 years of cotton both had monocropped cotton during the first 2 years of the study. In these cases the identical treatments were analyzed as additional replications of one treatment.

The double-cropped treatments had a nematicide applied to both potato and cotton. Therefore, cotton yields were not analyzed as a split-plot design but rather as a completely randomized design. Each cropping treatment × nematicide treatment combination was analyzed as a separate treatment. Cotton yields were subjected to analysis using the general linear model procedure, and the means were separated by Duncan's multiple-range test (Ott, 1993).

RESULTS

Nematodes: Differences among nematicide treatments within the same cropping system ($P < 0.05$) were observed in only one instance; in 1997 the population density of *B. longicaudatus* was lower following the double-cropped treatment where potato was treated with 1,3-D and cotton was treated with aldicarb than following either of the other two nematicide treatments. Therefore, only the whole-plot (cropping system) treatment means are reported.

Initial population densities of *B. longicaudatus* were highest ($P < 0.05$) following the double-cropped treatment in January 1997, but were not different from the monocropped potato followed by sorghum-sudangrass treatment in 1998 and were lower than the monocropped potato followed by sorghum-sudangrass treatment in 1999 (Table 2). Pi densities of *B. longicaudatus* following monocropped cotton for 2 or 3 years were lower than following potato and sorghum-sudangrass. In 1999, the lowest Pi densities for *B. longicaudatus* were found following either monocropped cotton or cotton rotated with potato.

Population densities of *M. incognita* second-stage juveniles (J2) in soil were lower following either monocropped cotton or cotton and potato in rotation than after potato followed by sorghum-sudangrass in 1998 and 1999 ($P < 0.05$). Pi densities of both *Pratylenchus* spp. and *Mesocriconema* sp. were lower following all other cropping treatments in comparison with the potato followed by sorghum-sudangrass in 1997 and 1999 ($P < 0.05$). Other plant-parasitic nematodes did not increase to large Pi numbers following any of the treatments. While differences were detected in some cases, these were not considered meaningful because of the low numbers.

Yields: Potato yields were lower for double-cropped potato than potato followed by sorghum-sudangrass in 1997, but were not different in 1998 ($P < 0.05$) (Table 3). Potato yields following 1 year of cotton were equivalent to and less than those following potato and sorghum-sudangrass in 1997 and 1998, respectively ($P < 0.05$).

When cotton was double-cropped with potato, yields were lower than for monocropped cotton when no nematicides were used ($P < 0.05$) (Table 4). When nematicides were applied to cotton double-cropped with potato, yields were comparable to yields in monocropping. Rotation of cotton with potato and sorghum-sudangrass did not affect cotton yields in comparison with monocropped cotton.

Discussion

Rotation of cotton with potato decreased population densities of *B. longicaudatus* and *M. incognita,* the most important nematodes associated with yield losses of potato (Crow et al., 2000b; Weingartner et al., 1993; Weingartner and Shumaker, 1983) and cotton (Crow et al., 2000a) in the region. Reductions in population density of *B. longicaudatus* were greater following each year of cotton. This may be because potato followed by sorghum-sudangrass has a longer combined growing season than cotton (250 days vs. 150 days), which would provide the nematodes a longer period to reproduce. Yields of both cotton and potato were not different following rotation than when either crop was monocropped.

Double-cropping of cotton with potato resulted in high population densities of *B. longicaudatus,* a virulent pathogen of both

TABLE 2. Effect of cropping systems on population densities of plant-parasitic nematodes assayed in January each year.

	Sampling date											
	January 1997			January 1998				January 1999				
Taxon	P[a]	C	D	P-P	C-C	D-D	C-P	P-P-P	C-C-C	D-D-D	C-P-C	C-C-P
BL[b]	30 b	28 b	108 a	61 a	36 b	68 a	51 ab	77 a	13 c	50 b	23 c	39 b
DH	1 a	<1 b	<1 b	2 a	1 ab	0 b	<1 b	5 a	0 b	0 b	0 b	<1 b
HS	3 a	<1 a	0 a	<1 a	1 a	0 a	4 a	0 a	2 a	0 a	4 a	<1 a
MI	2 a	<1 b	3 a	25 a	1 c	13 b	<1 b	70 a	1 b	47 a	1 b	10 b
MS	52 a	11 b	7 b	34 a	31 a	10 a	41 a	85 a	4 b	1 b	22 b	21 b
PM	7 ab	5 b	11 a	13 a	15 a	17 a	18 a	30 a	37 a	14 b	40 a	12 b
PS	14 a	1 b	1 b	17 a	20 a	9 a	23 a	51 a	10 b	7 b	9 b	7 b
TS	15 a	3 b	3 b	3 a	6 a	5 a	10 a	15 a	<1 b	<1 b	1 b	2 b

Means compared across columns within the same year followed by common letters are not different according to Duncan's multiple-range test ($P < 0.05$).

[a] P = potato followed by sorghum-sudangrass. C = cotton. D = potato and cotton double-cropped in the same year.

[b] BL: *Belonolaimus longicaudatus.* DH: *Dolichodorus heterocephalus.* HS: *Hemicycliophora* sp. MI: *Meloidogyne incognita.* MS: *Mesocriconema* sp. PM: *Paratrichodorus minor.* PS: *Pratylenchus* spp. TS: *Tylenchorhynchus* sp.

TABLE 3. Effects of cropping system and nematicide treatments from the previous 1 or 2 years on potato yields (kg/ha).

1997				1998			
Whole-plot[a]		Subplot		Whole-plot		Subplot	
Crop	Yield	Treatment	Yield	Crop	Yield	Treatment	Yield
PS[b]	27,001 a	U[c]	22,006 b	PS-PS	35,051 a	U	30,965 b
		A	24,634 b			A	35,742 ab
		D	34,364 a			D	38,446 a
C	29,549 a	U	23,473 b	C-C	31,864 b	U	27,568 a
		A	30,634 ab			A	32,991 a
		D	34,540 a			D	35,032 a
PC	16,155 b	U	10,730 b	PC-PC	34,562 ab	U	31,856 a
		A	10,429 b			A	35,305 a
		D	27,307 a			D	36,525 a

Means followed by common letters are not different according to Duncan's multiple-range test ($P < 0.05$). Whole-plot treatment means are compared within the same column. Subplot treatment means are compared within the same column, and within the same whole-plot treatment.
[a] Whole-plot = cropping system, subplot = nematicide treatment.
[b] PS: Potato followed by sorghum-sudangrass. C: Monocropped cotton. PC: Potato double-cropped with cotton.
[c] U: Untreated. A: Aldicarb. D: 1,3-dichloropropene.

crops. However, when a nematicide was applied to both crops, yields were comparable to either crop monocropped. Therefore, double-cropping of cotton with potato is economically viable if *B. longicaudatus* is managed with nematicides.

In the second and third years of this study, population densities of *M. incognita* were higher following continuous potato and sorghum-sudangrass than any other cropping treatment. Both cotton (Sasser and Carter, 1985) and sorghum-sudangrass (McSorley et al., 1994a, 1994b) are reported to be nonhosts for *M. incognita* race 1. The treatment differences may have been due to the presence of more weeds in the sorghum-sudangrass plots. Weeds were managed more intensively throughout the summer

TABLE 4. Effects of cropping system and nematicide treatments on cotton yields.

Cropping system	Nematicide treatment	Yield (kg/ha)
	1997	
Monocropped cotton	Untreated	2,535 d
Monocropped cotton	Aldicarb	3,247 bc
Monocropped cotton	1,3-D[a]	3,108 c
Double-cropped cotton[b]	Untreated-Untreated[c]	595 e
Double-cropped cotton	Aldicarb-Aldicarb	3,688 ab
Double-cropped cotton	Aldicarb-1,3-D	3,859 a
	1998	
Monocropped cotton	Untreated	2,973 a
Monocropped cotton	Aldicarb	2,762 a
Monocropped cotton	1,3-D	2,832 a
Double-cropped cotton	Untreated-Untreated	801 b
Double-cropped cotton	Aldicarb-Aldicarb	2,550 a
Double-cropped cotton	Aldicarb-1,3-D	2,438 a
Cotton rotated with potato	Untreated	2,731 a
Cotton rotated with potato	Aldicarb	2,729 a
Cotton rotated with potato	1,3-D	2,438 a

Means followed by common letters within years are not different according to Duncan's multiple-range test ($P < 0.05$).
[a] 1,3-Dichloropropene.
[b] Summer cotton double-cropped with winter potato.
[c]Double-cropped treatment received two nematicide treatments each year–one on potato and one on cotton.

months for cotton, an economic crop, than for sorghum-sudangrass, a cover crop. Weed roots that were galled by *M. incognita* included redweed (*Melochia corchorifolia*), pigweed (*Amaranthus hybridus*), and common purslane (*Portulaca oleracea*).

Data from this study show that rotation of cotton with potato is a viable practice in northeast Florida based on population densities of plant-parasitic nematodes and crop yields. Double-cropping of potato and cotton is viable only when *B. longicaudatus* is managed with nematicides. Further work to determine the effects of these cropping systems on other soilborne pathogens and production factors would be useful.

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