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Comparison of Nematode Population Densities on Six Summer Crops at Seven Sites in North Florida[1]

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Abstract: Densities of plant-parasitic nematodes were compared on six crops grown for forage during the summer of 1991 at seven sites in north central Florida. The cropping treatments were 'Howard' soybean (*Glycine max*), 'Deltapine 105' soybean, velvetbean (*Mucuna deeringiana*), 'California Blackeye #5' cowpea (*Vigna unguiculata*), 'Pioneer 3098' tropical corn (*Zea mays*), and 'Asgrow Chaparral' sorghum (*Sorghum bicolor*). Highest final densities (Pf) of *Meloidogyne incognita* and *Criconemella* spp. were obtained following corn or sorghum at most sites. The lowest Pf of *M. incognita* occurred after velvetbean at all seven sites, but Pf after cowpea were equivalent to Pf after velvetbean at four of seven sites. Cultivar choice is critical in planning rotations to suppress *M. incognita* because results obtained here and elsewhere have shown great differences among sorghum and cowpea cultivars. The Pf of *Pratylenchus* spp. were lowest following velvetbean at four of seven sites. There were no differences in densities of *Paratrichodorus minor* among crops, but populations increased at a greater rate if initial density (Pi) was low. Multiplication rates (Pf/Pi) of most nematode species on most crops varied inversely with Pi. An accurate impression of nematode multiplication and host status could not be obtained unless a range of Pi was examined.

Key words: corn, cover crop, cowpea, *Criconemella ornata, Criconemella sphaerocephala,* crop rotation, cropping system, *Glycine max,* nematode, *Meloidogyne incognita, Mucuna deeringiana, Paratrichodorus minor, Pratylenchus brachyurus, Pratylenchus scribneri,* sorghum, *Sorghum bicolor,* soybean, velvetbean, *Vigna unguiculata, Zea mays.*

The design of cropping sequences that minimize plant-parasitic nematode buildup and damage is receiving increasing interest in the southeastern United States (11,14,15). For such systems to be successful and flexible, it is critical to know the potential for buildup of serious nematode pests on a wide range of crops and cultivars. In regions with hot, wet summers, the choice of crops adapted to summer growing conditions may be limited. In north Florida and south Alabama, tropical corn (*Zea mays* L.) cultivars yield well during the summer months but can result in buildup of root-knot nematodes (7,12,20). Certain cultivars of sorghum (*Sorghum bi color* (L.) Moench) and sorghum-sudangrass (*S. bicolor* (L.) × *S. sudanese* (Piper) Stapf) are well adapted and have maintained low population densities of *Meloidogyne incognita* (Kofoid & White) Chitwood in Florida (7,12), but were not as effective when high densities of *M. arenaria* (Neal) Chitwood were present in peanut (*Arachis hypogaea* L.) rotations in Alabama (19). Cowpea (*Vigna unguiculata* (L.) Walp.) cultivars, generally well adapted to the hot summers of the Southeast, may vary widely in their susceptibility to *Meloidogyne* spp. (9). Recently, efforts have been made to introduce crops not widely cultivated in the region but that have potential for reducing nematode densities (18). For example, the benefits of velvetbean (*Mucuna deeringiana* (Bort.) Merr.) in reducing root-knot nematode densities were recognized in Florida in the 1920s (23). Velvetbean is an excellent green manure, and the efficacy of velvetbean accessions from Florida or Mozambique has been demonstrated recently against several *Meloidogyne* species (17).

The objective of this study was to compare nematode population buildup during the summer on forage crops of corn, sorghum, soybean (*Glycine max* (L.) Merr.), cowpea, and velvetbean at several sites in north Florida.

Materials and Methods

All experiments were conducted at the University of Florida Green Acres Agron-

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omy Research Farm in Alachua County during the summer of 1991. The seven experiments were conducted on seven different sites, which differed in the cover crops maintained on them during the winter of 1990–91. These sites will be referred to by the cover crop name: wheat (*Triticum aestivum* L.); rye (*Secale cereale* L. cv. Wrens Abruzzi); lupine-1 (*Lupinus angustifolius* L.); lupine-2 (*L. angustifolius*); clover ('Dixie' crimson clover [*Trifolium incarnatum* L.]); vetch (hairy vetch [*Vicia villosa* Roth.]); and fallow (no crops or weeds). All sites were located on Arredondo fine sand (loamy, siliceous, hyperthermic Grossarenic Paleudults). Soil texture among the seven sites ranged from 90–92% sand, 3–4.5% silt, and 5–6% clay, with 1.5–2.5% organic matter and pH 5.4–6.1.

At each site, the experimental design was a randomized complete block with six treatments: 'Howard' soybean, 'Deltapine 105' soybean, velvetbean, 'California Blackeye #5' cowpea, 'Pioneer 3098' tropical corn, and 'Asgrow Chaparral' grain sorghum. Each treatment was replicated four times, except at the vetch site, where five replications were used. Individual plots comprised four rows, 3.0 m long and 76 cm apart.

Plots at the lupine-1 site were planted 23 May 1991; plots at the vetch, rye, lupine-2, and clover sites were planted 24 May 1991; and plots at the wheat and fallow sites were planted 28 May 1991. Soybean seeds were planted 2.5 cm apart, sorghum 5 cm apart, cowpea 7.5 cm apart, corn 23 cm apart, and velvetbean 30 cm apart in 76-cm-wide rows. Fertilizers, insecticides, and fungicides were applied as needed according to local recommendations for each crop (6). Insecticide applications included low rates of carbofuran (0.15 kg a.i./ha on corn; 0.10 kg a.i./ha on sorghum) applied at planting for management of lesser cornstalk borer (*Elasmopalpus lignosellus* Zeller). No herbicides were used; weed management was accomplished by two mechanical cultivations and by hand weeding. Overhead irrigation was applied to all plots as needed.

Soil samples for nematode analysis were collected by removing and compositing six cores 2.5 cm d × 20 cm long. A soil sample was collected from each plot at planting to assay initial nematode densities (Pi). Final densities (Pf) were estimated from samples collected on 23 August from clover and rye sites, 11 September from lupine-1 and lupine-2, 20 September from vetch, and 24 September from wheat and fallow. Nematodes were extracted from 100-cm^3 soil subsamples with a modified sieving and centrifugation procedure (8). On the final sampling dates, all crops were harvested for forage yield. At harvest, all plants in the center two rows of each plot were cut at ground level, and all above-ground plant material was removed, dried, and expressed as dry matter yield per ha.

Nematode counts were log-transformed ($\log_{10}[x + 1]$) before analysis of variance, and when significant ($P \leq 0.05$) treatment effects were detected, means were separated using Duncan's multiple-range test (5). Forage yield data were not analyzed statistically, because the crop treatments were very different. Mean yields ± standard error were calculated for each crop at each site.

RESULTS

Meloidogyne incognita was present at all seven sites, and mean Pi for *M. incognita* ranged from <10 second-stage juveniles (J2)/100 cm^3 in wheat, fallow, and rye sites to >350/100 cm^3 in clover and vetch sites (Table 1). Trends in *M. incognita* Pf following the various crops were similar at all sites. Velvetbean resulted in the lowest (or equivalent to lowest) Pf of *M. incognita* at all seven sites (Table 2). The Pf of *M. incognita* was also comparatively low following cowpea. At six of seven sites, Pf following corn was equivalent to the highest Pf among the six crops evaluated. The Pf following 'Asgrow Chaparral' sorghum was equivalent to or exceeded Pf after corn at five of seven sites. The Pf was greater than Pi at all sites following corn, sorghum, or 'Howard' soybean, even though Pi was very high (>350/100 cm^3) at some sites

TABLE 1. Initial nematode densities (Pi) and ratio between density (Pf) and Pi on six crops at seven sites in Alachua County, Florida, 1991.

Site†	Pi (Nematodes per 100 cm^3 soil)‡	Pf/Pi§ 'Howard' soybean	'Deltapine 105' soybean	Velvetbean	Cowpea	Corn	Sorghum
			Meloidogyne incognita				
Wheat	3 ± 1	36.1	6.9	0.7	9.6	271.1	32.6
Fallow	5 ± 5	28.6	153.2	16.4	34.6	55.2	66.1
Rye	6 ± 3	21.5	7.8	1.9	4.6	165.6	25.6
Lupine-1	20 ± 2	9.7	2.2	0.4	0.6	38.7	12.3
Lupine-2	71 ± 43	2.4	0.4	0.02	0.7	17.5	6.6
Clover	353 ± 78	3.1	3.6	0.5	0.2	2.0	1.6
Vetch	462 ± 163	1.3	0.4	0.2	0.2	2.7	1.8
			Pratylenchus spp.				
Fallow	0	—	—	—	—	—	—
Lupine-2	4 ± 2	12.4	12.9	1.2	4.1	36.2	4.2
Lupine-1	6 ± 4	2.9	5.8	0.4	3.6	3.1	0.8
Clover	8 ± 4	3.7	6.7	6.1	3.1	3.3	17.3
Wheat	19 ± 10	15.7	19.9	3.2	16.8	23.8	10.5
Rye	22 ± 5	4.2	3.4	1.9	3.2	6.7	9.7
Vetch	23 ± 5	2.0	4.7	2.6	2.9	2.5	2.1
			Paratrichodorus minor				
Lupine-1	3 ± 2	7.7	4.7	7.4	3.9	22.6	15.6
Fallow	4 ± 1	19.8	8.0	8.1	17.6	18.1	31.1
Rye	10 ± 4	0.8	1.8	1.5	1.9	1.2	0.8
Wheat	18 ± 5	1.6	1.7	1.1	1.1	1.2	4.1
Lupine-2	22 ± 8	0.8	0.8	0.6	1.3	0.6	0.7
Clover	25 ± 8	0.7	1.3	1.2	1.9	0.8	1.5
Vetch	186 ± 44	0.1	0.2	0.4	0.4	0.2	0.2
			Criconemella spp.				
Lupine-1	3 ± 1	2.4	3.6	1.8	2.7	27.4	32.7
Lupine-2	14 ± 10	1.2	0.4	0.2	0.8	7.3	8.3
Clover	30 ± 11	0.9	0.7	0.8	1.7	5.1	27.6
Rye	31 ± 14	4.6	1.0	1.8	5.9	16.4	47.6
Vetch	54 ± 18	0.6	0.7	0.5	1.5	2.6	3.0
Fallow	92 ± 42	1.5	1.1	1.5	1.2	10.5	3.6
Wheat	181 ± 30	0.6	1.0	0.5	1.0	2.5	3.9

† Sites arranged in order of Pi for each nematode genus.
‡ Pi data are means ± standard error of five (vetch site) or four (all other sites) replications.
§ Pf/Pi not computed for *Pratylenchus* spp. at the fallow site because Pi = 0. *Paratylenchus* spp. was present in the clover site at an initial density of 127 ± 8/100 cm^3; Pf/Pi < 0.7 for *Paratylenchus* spp. on all crops at this site.

(Table 1). In general, Pf/Pi of *M. incognita* following most crops were highest when Pi was low (<10 J2/100 cm^3). Pf/Pi was <1.0 after velvetbean and cowpea, except when Pi was low (<10/100 cm^3).

Pratylenchus scribneri Steiner was present at the vetch, wheat, lupine-1, and lupine-2 sites. *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven was found at the fallow site. In the final samples from the rye site, a mixture of 64% *P. brachyurus* and 36% *P. scribneri* was found, based on percentage composition of mature female specimens. At the clover site, Pf consisted of 67% *P. brachyurus* and 33% *P. scribneri.* Final densities of *Pratylenchus* spp. were lowest following velvetbean at four of seven sites (Table 2). However, for nearly all crops and locations, Pf/Pi > 1.0 for *Pratylenchus* spp. (Table 1).

Criconemella spp. were most common in the fallow and wheat sites. Of the ring nematodes recovered, *Criconemella ornata* (Raski) Luc & Raski was the only species observed at the fallow, wheat, and lupine-2 sites. Based on mature females at Pf, 88% *C. ornata* and 12% *C. sphaerocephala* (Taylor) Luc & Raski were present at the lupine-1 site, 70% *C. ornata* and 30% *C. sphaerocephala* at the clover site, and 68% *C.*

TABLE 2. Final nematode densities (Pf) on six crops at seven sites in Alachua County, Florida, 1991.

		Final nematode densities per 100 cm³ soil						
Crop	Cultivar	Wheat	Fallow	Rye	Lupine-1	Lupine-2	Clover	Vetch
				Meloidogyne incognita				
Soybean	Howard	101 b	137 c	140 b	197 a	172 b	1,100 a	607 a
Soybean	Deltapine 105	19 b	736 c†	50 bc	44 b	29 c	1,268 a	160 b
Velvetbean	—	2 c	78 c	12 d	8 c	1 d	179 b	69 b
Cowpea	California Blackeye #5	27 b	166 c	30 c	11 c	48 c	86 b	90 b
Corn	Pioneer 3098	759 a	265 b	1,076 a	782 a	1,244 a	706 a	1,262 a
Sorghum	Asgrow Chaparral	91 b	318 a	166 b	248 a	467 ab	547 a	815 a
				Pratylenchus spp.				
Soybean	Howard	302 a	60	93 bc	18 ab	52 ab	32 b	48
Soybean	Deltapine 105	382 a	12	75 bc	36 a	54 ab	57 ab	108
Velvetbean	—	62 b	14	41 c	3 c	5 c	52 ab	60
Cowpea	California Blackeye #5	322 a	22	71 bc	22 ab	17 bc	26 b	68
Corn	Pioneer 3098	457 a	26	148 ab	19 ab	152 a	28 b	59
Sorghum	Asgrow Chaparral	202 ab	18	214 a	5 bc	18 bc	147 a	48
				Paratrichodorus minor				
Soybean	Howard	28	69	8	24 bc	19	18	25
Soybean	Deltapine 105	30	28	18	15 c	18	33	37
Velvetbean	—	20	28	15	24 bc	14	29	74
Cowpea	California Blackeye #5	19	62	18	12 c	28	47	67
Corn	Pioneer 3098	22	63	12	72 a	12	19	30
Sorghum	Asgrow Chaparral	73	109	8	50 ab	16	36	27
				Criconemella spp.				
Soybean	Howard	113 c	137	143 bc	7 b	17 b	26 c	35
Soybean	Deltapine 105	180 bc	98	30 d	11 b	6 bc	22 c	36
Velvetbean	—	94 c	136	55 cd	6 b	4 c	25 c	26
Cowpea	California Blackeye #5	176 bc	113	183 bc	8 b	11 bc	52 bc	80
Corn	Pioneer 3098	454 ab	961	510 ab	82 a	102 a	152 b	144
Sorghum	Asgrow Chaparral	699 a	329	1,484 a	98 a	117 a	828 a	161
			Xiphinema spp.				*Paratylenchus* spp.	
Soybean	Howard	—‡	3	—	—	—	44	—
Soybean	Deltapine 105	—	2	—	—	—	91	—
Velvetbean	—	—	5	—	—	—	46	—
Cowpea	California Blackeye #5	—	12	—	—	—	47	—
Corn	Pioneer 3098	—	5	—	—	—	48	—
Sorghum	Asgrow Chaparral	—	3	—	—	—	80	—

Data are untransformed means of five (vetch site) or four (all other sites) replications. For each nematode genus, means in columns followed by the same letter are not different ($P \leq 0.05$), according to Duncan's multiple-range test performed on log-transformed data. No letters indicate no differences ($P \leq 0.05$) for nematode genus at this site.

† A standard error of ±734 is associated with this mean.

‡ *Xiphinema* was present in the fallow site and *Pratylenchus* in the clover site. Dashes (—) indicate that these genera were absent from the other sites.

ornata and 32% *C. sphaerocephala* at the rye site. The vetch site was the only location in which *C. sphaerocephala* was dominant, with 71% *C. sphaerocephala* and 29% *C. ornata*. Final densities of *Criconemella* spp. were highest following corn and sorghum (Table 2). The Pf after sorghum was greater than Pf after velvetbean, cowpea, or either soybean cultivar at five of seven sites ($P \leq 0.05$). Densities of *Criconemella* spp. were maintained at levels roughly similar to Pi following four of the crops, but they increased twofold or more following corn or sorghum at all sites (Table 1).

Paratrichodorus minor (Colbran) Siddiqi was present at all sites but was affected little by the summer crop grown (Table 2). In nearly all cases, Pf of *P. minor* was between 8–74/100 cm^3. The rate of population increase (Pf/Pi) for this nematode was strongly related to Pi rather than to host crop. For *P. minor* on all crops at all sites, Pf/Pi was <2.0 if Pi was $\geq 10/100$ cm^3, but Pf/Pi was ≥ 3.9 if Pi was $<10/100$ cm^3 (Table 1).

Xiphinema spp. and *Paratylenchus* spp. were recovered at only one site and were unaffected by the crop grown (Table 2). *Paratylenchus* spp. declined under all crops at the only site at which it occurred (clover).

Dry matter forage yields in excess of 4,000 kg/ha were obtained for all crops at all sites (Table 3). Generally, greatest dry matter yields were obtained with the very large corn and sorghum plants. Dry matter yields of four of six crops were numerically greatest at the lupine-2 site, whereas yields of three of six crops were numerically least at the clover site (Table 3). No crop yields were correlated ($P \leq 0.05$) with nematode densities across sites.

Discussion

All crops appeared to be well adapted to summer growing conditions in North Florida. The dry matter yields accumulated by the six crops suggest that all may have utility as forages and (or) green manures.

Because the cover crops planted during the winter of 1990–91 varied with site, it was not possible to make direct comparisons of effects of cover crops on initial nematode densities. Nevertheless, the trends observed among Pi of *M. incognita* were expected based on site history. Lowest Pi were observed in sites planted to rye or wheat, neither of which support winter populations of *M. incognita* well (10,16). The highest Pi observed here were in sites following vetch and crimson clover, both of which increase *M. incognita* populations over the winter (10,11). No data are available on effects of a lupine cover crop on *M. incognita* densities during the winter. Both sites planted to lupine during winter were intermediate (20–71 J2/100 cm^3) in Pi of *M. incognita* in the spring of 1991.

Velvetbean was the most effective of the six summer crops in maintaining low populations of *M. incognita,* which is consistent with results reported recently for several *Meloidogyne* spp. (17). Our results suggest that it may also have some efficacy against *Pratylenchus* spp. The cowpea cultivar California Blackeye #5 also maintained comparatively low populations of *M. incognita* in some sites, although the utility of cowpea as a rotation crop will depend on the cultivar selected, because a wide range of response of cowpea cultivars to *Meloidogyne* spp. has been observed (9). Densities of *Meloidogyne* spp. typically increase on tropical corn cultivars (7,11,12,20), and at several sites in these studies Pf following corn were greater than Pf following soybean, an excellent host of several *Meloidogyne* species (22).

The high Pf of *M. incognita* following 'Asgrow Chaparral' sorghum in all sites was unexpected. In recent field tests (11,12), low Pf of *M. incognita* resulted after the forage sorghum 'DeKalb FS25E', the grain sorghum 'DeKalb BR64', or the sorghum-sudangrass hybrid 'DeKalb SX-17'. Evidently, selection of the correct sorghum cultivar is critical for management of *M. incognita.* Additional data are needed to determine the responses of *M. incognita* populations to a number of sorghum cultivars. Of the cultivars evaluated thus far, most are poor hosts of *Meloidogyne* spp., although a range of responses exists (4,13).

Of the nematodes observed in this study, *M. incognita* is the most suitable target for management by crop selection. It is the key nematode pest in many cropping systems in north central Florida (11), and it showed consistent responses to the six crops evaluated here. In contrast, selection among the six crops evaluated here would make

TABLE 3. Dry matter yields (kg/ha) of six crops at seven sites in Alachua County, Florida.

Site	'Howard' soybean	'Deltapine 105' soybean	Velvetbean	Cowpea	Corn	Sorghum
Lupine-2	12,800 ± 673	10,400 ± 479	13,875 ± 1,320	5,300 ± 208	21,150 ± 981	16,500 ± 1,775
Rye	10,250 ± 806	7,800 ± 683	9,050 ± 614	6,215 ± 661	13,450 ± 830	15,050 ± 954
Wheat	9,300 ± 592	6,750 ± 50	7,900 ± 736	5,395 ± 529	13,925 ± 1,496	7,700 ± 1,008
Vetch	8,555 ± 643	7,000 ± 648	9,100 ± 420	4,700 ± 283	15,200 ± 1,236	11,200 ± 1,098
Fallow	8,320 ± 445	5,800 ± 346	10,650 ± 338	5,295 ± 460	18,200 ± 1,655	16,600 ± 2,211
Lupine-1	6,650 ± 486	5,650 ± 670	12,500 ± 1,070	4,500 ± 486	12,450 ± 1,863	11,450 ± 971
Clover	6,650 ± 907	5,700 ± 733	7,125 ± 574	4,340 ± 514	14,800 ± 1,383	11,900 ± 954

Data are means ± standard error of five (vetch site) or four (all other sites) replications.

little difference in Pf of *P. minor*. Although *Criconemella* spp. increased to higher levels on corn or sorghum than on the other crops, these nematodes would be unlikely to cause economic crop damage in most situations (11), although damage by *C. ornata* to peanut was reported (1). Both *Pratylenchus* spp. responded inconsistently to the crops selected here. *Pratylenchus brachyurus,* which was predominant at the rye and fallow sites, was unaffected by summer crop at the fallow site but was reduced by velvetbean at the rye site. At the vetch site, *P. scribneri* was unaffected by summer crop but was reduced by velvetbean at the wheat site.

Multiplication rates of nematode populations (Pf/Pi) depended on both host and Pi. Although some authors use Pf/Pi as an indicator of host plant resistance, the magnitude of this ratio varies inversely with Pi (2,3). The concept of an equilibrium density (for Pf) is well established in nematology (21), and thus it is evident that Pf/Pi must decline as Pi increases. Therefore, it is necessary to assess host status over the entire range rather than at a single Pi. For example, even velvetbean, a root-knot suppressive crop (23), sometimes resulted in an increase in *M. incognita* if Pi was low ($\leq$6/100 cm^3 soil) (Table 1). The inverse relationship between Pf/Pi and Pi was most clearly seen with *P. minor,* which multiplied rapidly (Pf/Pi $\geq$ 3.9) at low Pi but increased slowly or decreased (Pf/Pi $\leq$ 1.0) at higher Pi, regardless of host crop (Table 1). With *Criconemella* spp., the magnitude of Pf/Pi depended on both density and host, with greater increases observed on corn and sorghum and on the other crops.

There remains a great need to increase our knowledge of the effects of many crop cultivars over the range of densities of all common plant-parasitic nematode species. As information on these various combinations increases, growers will have more choices available in designing systems that minimize adverse impact from nematodes.

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