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Effect of Tillage and Crop Residue Management on Nematode Densities on Corn

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Abstract: Effects of winter cover crop management on nematode densities associated with a subsequent corn (*Zea mays*) crop were examined in five sites in north Florida. Two sites had received winter cover crops of lupine (*Lupinus angustifolius*), and one site each had rye (*Secale cereale*), hairy vetch (*Vicia villosa*), and crimson clover (*Trifolium incarnatum*). In each site, five different management regimes were compared: 1) conventional tillage after the cover crop was removed for forage; 2) conventional tillage with the cover crop retained as green manure; 3) no-till with the cover crop mowed and used as a mulch; 4) no-till with the cover crop removed as forage; and 5) fallow. Sites were sampled at corn planting and harvest for estimates of initial (Pi) and final (Pf) nematode population densities, respectively. Whether the cover crop was removed as forage or retained as green manure or mulch had no effect ($P > 0.10$) on population densities of any plant-parasitic nematode before or after corn at any site. Differences between conventional-till and no-till treatments were significant ($P \leqslant 0.10$) only in one experiment for *Paratrichodorus minor* and two experiments for *Pratylenchus* spp. Compared with other treatments, fallow reduced ($P \leqslant 0.05$) Pi of *P. minor* in two of three cases and Pf of *Meloidogyne incognita* in one of five sites, but enhanced soil Pf of *Pratylenchus* spp. in three of five sites. Tillage practices and management of cover crop residues had little consistent effect on nematodes, and these practices should be considered based on agronomic benefits rather than for nematode management.

Key words: corn, *Criconemella* spp., cover crop, cropping system, green manure, *Meloidogyne incognita*, nematode, organic amendment, *Paratrichodorus minor*, *Pratylenchus* spp., sustainable agriculture, tillage, *Zea mays*.

Numerous cultural practices can be beneficial by reducing population densities of plant-parasitic nematodes (16). Two alternatives that can be particularly applicable in the southeastern United States are crop rotation (4,7) and tillage practices (11). Crop rotation has been particularly important in minimizing nematode population increase in some cropping systems (4,7,15) and continues to be studied intensively (5, 8,9). Consistent effects of tillage practices on nematode population densities have been much less evident (9,11). It is our conclusion (9) that, under Florida growing conditions, rotation is much more important in managing plant-parasitic nematodes than is the choice of a crop residue management program. Nevertheless, the management and amount of residues remaining from cover crops can vary with crop species and tillage practices, possibly affecting nematodes as well.

Regardless of their effects on plant-parasitic nematodes, cover cropping and tillage practices have many important agronomic benefits. Cover crops such as rye (*Secale cereale*) not only provide cover to protect the soil against erosion but also provide mulch to compete against weeds, moderate soil temperature, and conserve water for succeeding crops such as no-till corn (*Zea mays*) (1). Reduced tillage or no-till can be a means of reducing inputs of N fertilizers in corn production. Nitrogen is the single most important fertilizer input and is required in the largest quantities for crop production (12). If agricultural systems in the United States are to become more "sustainable" (i.e., requiring less input of synthetic materials), then current usage of synthetic N must be reduced and alternatives found. Legumes are one source of organic N that can be used as cover crops to be sacrificed for succeeding crops in double-cropping systems (13). The management of cover crops and their residues will be critical to achieve success-

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ful performance of corn and other crops in low-input systems. The objective of our study was to determine the effect of tillage and cover crop residue management on nematode densities in a subsequent crop of corn receiving low or no fertilizer input.

Materials and Methods

Five separate experiments were conducted during 1992 and 1993 at the University of Florida Green Acres Agronomy Research Farm in Alachua County. The soil type at all sites was an Arredondo fine sand (loamy, siliceous, hyperthermic Grossarenic Paleudults; 94% sand, 2% silt, 4% clay), with pH 5.6–5.8 and 1.5–2.0% organic matter. All experiments were conducted with 'Pioneer Brand 3320' corn planted in the spring following winter cover crops of 'Tift Blue' lupine (*Lupinus angustifolius*), 'Wrens Abruzzi' rye, 'Dixie' crimson clover (*Trifolium incarnatum*), or hairy vetch (*Vicia villosa*).

In every experiment, five different crop residue management regimes, or tillage treatments, were used: 1) conventional tillage after the winter cover crop was cut and removed for forage; 2) conventional tillage using the winter crop for green manure, such that tillage operations were conducted over the uncut cover crop; 3) no-till in which the cover crop was mowed and left in place as a mulch; 4) no-till in which the winter cover crop was cut and removed for forage; and 5) fallow, without a cover crop and subjected to conventional tillage. In conventional-till plots, the soil was rototilled twice between the end of the cover crop and the planting of corn, whereas residues from old root systems remained undisturbed in no-till plots. In every experiment, these five treatments were arranged in four randomized complete blocks.

In the 1992 test following a lupine cover crop, corn was planted 10 April with a two-row Brown-Harden Superseeder (Brown Mfg. Co., Banks, AL), to achieve a final plant population density of 76,500/ha. Individual plots consisted of four rows, 3.65 m long. Corn plots were sprayed preemergence with 1.7 kg a.i. atrazine/ha + 1.12 kg a.i. metoachlor/ha for residual weed control. Additional weed control was obtained from a post-directed application of 0.5 kg a.i. gramoxone/ha. No inorganic N was applied, but plots received a total of 6 kg P, 160 kg K, 25 kg Mg, and 50 kg S/ha. Plots were watered by overhead sprinkler irrigation every 4 days when natural rainfall was insufficient. Plots were harvested on 4 August by removing all ears from the center two rows of each plot and drying kernels to 15.5% moisture. Yield data are reported elsewhere (2). Soil samples for nematode assays were collected at corn planting for initial population densities (Pi) and at harvest for final population densities (Pf). Each soil sample consisted of six cores 2.5-cm-d × 20 cm deep collected from plant rows within a plot in a systematic pattern. A 100-cm^3 subsample was removed for nematode extraction by a modified sieving and centrifugation procedure (3).

Similar procedures were followed in the 1992 experiments following rye and clover, except that nematode samples were collected only at harvest (Pf). The 1993 experiment following lupine was identical to the 1992 experiment following lupine, except that corn planting was 19 March 1993 and harvest was 27 July 1993. The same planting and harvest dates were used for the 1993 experiment following vetch, and most other aspects of the protocol were similar to the experiment following lupine, except for the experimental design: plots consisted of eight rows instead of four and were split into two fertility levels, either 0 or 134 kg N/ha. Of the total N, 40% was applied at planting, 20% was sidedressed when corn was 30 cm tall, and 40% was sidedressed when corn was 60 cm tall.

Nematode data were log-transformed ($\log_{10}[x + 1]$) before analysis. Three single degree of freedom orthogonal contrasts were examined: 1) treatments with forage cut and removed vs. treatments with above-ground plant residues retained as mulch or green manure; 2) conventional-till vs. no-till treatments; and 3) fallow vs. the other treatments. For the 1993 experiment following vetch, analysis of variance (ANOVA) was used to test for significant ($P \leq 0.10$) effects due to tillage treatment, fertility level, and the tillage × fertility interaction. The three abovementioned contrasts were applied separately within each fertility level.

Results

The predominant plant-parasitic nematodes at all sites were *Criconemella* spp. (primarily *C. ornata*), *Meloidogyne incognita*, *Paratrichodorus minor*, and *Pratylenchus* spp. (primarily *P. scribneri*) (Tables 1–5). *Paratylenchus* spp. occurred at the site following clover, but no differences ($P > 0.10$) due to treatment were observed (data not shown).

The contrast between treatments in which cover crops were removed for forage and treatments in which residues were left in place as mulch or green manure was not significant ($P > 0.10$) for any nematode, site, or sampling date; therefore, this contrast is not shown in Tables 1–5. Differences between conventional-till and no-till treatments were infrequent. Final densities of *Pratylenchus* spp. were affected ($P < 0.10$) by tillage in two of five experiments (Tables 2,5), but in opposite ways. Initial density of *P. minor* was less ($P \leq 0.05$) in conventional-till than in no-till plots in the 1993 test following vetch (Table 5).

Of the five management regimes tested, fallow had the most effect on nematode population densities. Initial densities of *P. minor* were lower ($P \leq 0.05$) following fallow than the other four treatments in two of three tests (Tables 3,5) in which Pi was measured. Final densities of *M. incognita* were lowest after fallow in one of five tests (Table 4), but Pf of *Pratylenchus* spp. in soil were greater ($P \leq 0.05$) following fallow than following the other treatments in three of five tests (Tables 2,3,5).

In the test in which different N fertility levels were imposed (Tables 4,5), Pi of all nematodes were unaffected by fertility level. Final nematode population densities of *M. incognita* and *P. minor* were increased ($P \leq 0.05$) on corn that received a higher N rate, but the opposite trend occurred with *Pratylenchus* spp. No significant ($P > 0.10$) tillage treatment × fertility level interaction was observed for any nematode or sampling date.

Discussion

Fallowing has been recognized as a means for reducing nematode population densities, but is usually not recommended due to adverse effects on soil fertility, structure, and conservation (4,14,16). In our studies of a corn crop with low or no input of synthetic N, rotation with a cover crop, particularly a legume, increased corn yield over a rotation with fallow (2). Thus, although population densities of potential

TABLE 1. Effects of tillage and crop residue management treatments on initial (Pi) and final (Pf) nematode population densities on corn, 1992, following a winter cover crop of lupine.

	Nematodes/100 cm^3 soil							
	Criconemella spp.		*Meloidogyne incognita*		*Paratrichodorus minor*		*Pratylenchus* spp.	
Treatment†	Pi	Pf	Pi	Pf	Pi	Pf	Pi	Pf
Conventional-till/forage	92	351	124	695	45	17	37	72
Conventional-till/green manure	105	145	32	584	28	16	66	154
No-till/mulch	94	376	16	1,400	49	10	20	98
No-till/forage	90	329	18	534	46	3	46	128
Fallow	212	317	84	646	25	14	62	242

Data are untransformed means of four replications. Data were transformed by $\log_{10}(x + 1)$ before analysis. The contrasts of fallow vs. other treatments and conventional vs. no-till treatments were not significant at $P \leq 0.10$ for any nematode or sampling date.

† Treatments were: 1) conventional tillage after the cover crop was removed for forage; 2) conventional tillage with the cover crop retained as green manure; 3) no-till with the cover crop mowed and used as mulch; 4) no-till with the cover crop removed as forage; and 5) fallow, without a cover crop.

TABLE 2. Effects of tillage and crop residue management treatments on final nematode population densities on corn, 1992, following a winter cover crop of rye or clover.

	Nematodes/100 cm^3 soil							
	Criconemella spp.		*Meloidogyne incognita*		*Paratrichodorus minor*		*Pratylenchus* spp.	
Treatment†	Rye	Clover	Rye	Clover	Rye	Clover	Rye	Clover
Conventional-till/forage	534	161	167	728	4	9	178	80
Conventional-till/green manure	178	289	229	753	10	7	167	99
No-till/mulch	504	194	172	624	17	4	151	123
No-till/forage	350	415	387	809	20	6	164	131
Fallow	368	500	236	830	11	9	182	246
Contrast								
Fallow vs. other treatments	ns	ns	ns	ns	ns	ns	ns	*
Conventional vs. no-till	ns	ns	ns	ns	ns	ns	ns	10%

Data are untransformed means of four replications. Data were transformed by $\log_{10}(x + 1)$ before analysis. * indicates contrast significant at $P \leq 0.05$; 10% = significant at $P \leq 0.10$; ns = not significant at $P \leq 0.10$.

† Treatments were: 1) conventional tillage after the cover crop was removed for forage; 2) conventional tillage with the cover crop retained as green manure; 3) no-till with the cover crop mowed and used as mulch; 4) no-till with the cover crop removed as forage; and 5) fallow, without a cover crop.

nematode pests such as *M. incognita* and *P. minor* can be lowered by fallowing, the benefits from nematode reduction may be outweighed by adverse effects on fertility and yield, which would probably limit widespread adoption of fallowing as an agronomic practice.

Comparison of methods for managing an existing cover crop is more practical than comparison of cover crops with fallow. As in previous work in this system (9), we observed relatively few consistent effects on nematode population densities due to tillage; thus, nematode management should not be an important factor in selecting a conventional-till or a no-till system. Likewise, whether the above-ground cover crop residues were removed or left on the field as a mulch or green manure had no significant effect on soil nematode population densities. The additional biomass retained on the field as mulch or green manure may have enhanced fertility and conserved soil moisture, and resulted in increased corn yield in one of three tests conducted in 1992 (2).

TABLE 3. Effects of tillage and crop residue management treatments on initial (Pi) and final (Pf) nematode population densities on corn, 1993, following a winter cover crop of lupine.

	Nematodes/100 cm^3 soil							
	Criconemella spp.		*Meloidogyne incognita*		*Paratrichodorus minor*		*Pratylenchus* spp.	
Treatment†	Pi	Pf	Pi	Pf	Pi	Pf	Pi	Pf
Conventional-till/forage	106	356	54	1,170	28	30	16	110
Conventional-till/green manure	156	310	13	516	40	24	12	96
No-till/mulch	140	471	58	681	38	65	15	87
No-till/forage	92	315	56	583	33	31	8	114
Fallow	85	643	28	417	15	9	22	249
Contrast								
Fallow vs. other treatments	ns	ns	ns	ns	*	ns	ns	*
Conventional vs. no-till	ns	ns	ns	ns	ns	ns	ns	ns

Data are untransformed means of four replications. Data were transformed by $\log_{10}(x + 1)$ before analysis. * indicates contrast significant at $P \leq 0.05$; ns = not significant at $P \leq 0.10$.

† Treatments were: 1) conventional tillage after the cover crop was removed for forage; 2) conventional tillage with the cover crop retained as green manure; 3) no-till with the cover crop mowed and used as mulch; 4) no-till with the cover crop removed as forage; and 5) fallow, without a cover crop.

TABLE 4. Effects of tillage and crop residue management treatments on initial (Pi) and final (Pf) population densities of *Criconemella* spp. and *Meloidogyne incognita* on corn, 1993, fertilized with two levels of nitrogen (0 or 134 kg N/ha), following a winter cover crop of vetch.

	Nematodes/100 cm^3 soil							
	Criconemella spp.				*Meloidogyne incognita*			
	Pi		Pf		Pi		Pf	
Tillage treatment†	0 N	134 N	0 N	134 N	0 N	134 N	0 N	134 N
Conventional-till/forage	435	227	938	450	33	31	547	859
Conventional-till/green manure	140	121	666	1,061	50	31	532	893
No-till/mulch	362	290	739	526	8	10	331	1,085
No-till/forage	144	239	516	919	18	43	793	860
Fallow	259	325	1,062	1,726	12	10	207	195
Contrast								
Fallow vs. other treatments	ns	ns	ns	ns	ns	ns	*	***
Conventional vs. no-till	ns	ns	ns	ns	ns	ns	ns	ns
ANOVA effects								
Tillage treatment	10%		ns		*		***	
Fertilizer rate	ns		ns		ns		*	
Tillage × fertilizer	ns		ns		ns		ns	

Data are untransformed means of four replications. Data were transformed by $\log_{10}(x + 1)$ before analysis. *, *** indicate significant effects at $P \leq 0.05$ and $P \leq 0.001$, respectively; 10% = significant at $P \leq 0.10$; ns = not significant at $P \leq 0.10$.
† Treatments were: 1) conventional tillage after the cover crop was removed for forage; 2) conventional tillage with the cover crop retained as green manure; 3) no-till with the cover crop mowed and used as mulch; 4) no-till with the cover crop removed as forage; and 5) fallow, without a cover crop.

Numerous cultural practices make up agricultural systems, but effects of these on nematode population densities are unknown in many situations. On nutrient-poor, sandy soils in Florida in which *Meloidogyne* spp. are the principal nematode pests, rotation crops (5,7–9) or winter cover crops (6,7) affect nematode density

TABLE 5. Effects of tillage and crop residue management treatments on initial (Pi) and final (Pf) population densities of *Paratrichodorus minor* and *Pratylenchus* spp. on corn, 1993, fertilized with two levels of nitrogen (0 or 134 kg N/ha), following a winter cover crop of vetch.

	Nematodes/100 cm^3 soil							
	Paratrichodorus minor				*Pratylenchus* spp.			
	Pi		Pf		Pi		Pf	
Tillage treatment†	0 N	134 N	0 N	134 N	0 N	134 N	0 N	134 N
Conventional-till/forage	125	158	18	137	4	9	142	65
Conventional-till/green manure	97	106	18	103	6	8	131	54
No-till/mulch	254	177	65	54	12	16	83	69
No-till/forage	202	243	31	50	11	10	74	86
Fallow	30	24	28	48	9	9	165	139
Contrast								
Fallow vs. other treatments	***	***	ns	ns	ns	ns	ns	*
Conventional vs. no-till	*	*	ns	ns	ns	ns	*	ns
ANOVA effects								
Tillage treatment	***		ns		ns		10%	
Fertilizer rate	ns		*		ns		10%	
Tillage × fertilizer	ns		ns		ns		ns	

Data are untransformed means of four replications. Data were transformed by $\log_{10}(x + 1)$ before analysis. *, *** indicate significant effects at $P \leq 0.05$ and $P \leq 0.001$, respectively. 10% = significant at $P \leq 0.10$; ns = not significant at $P \leq 0.10$.
† Treatments were: 1) conventional tillage after the cover crop was removed for forage; 2) conventional tillage with the cover crop retained as green manure; 3) no-till with the cover crop mowed and used as mulch; 4) no-till with the cover crop removed as forage; and 5) fallow, without a cover crop.

and management. However, little or no consistent effect can be attributed to tillage (9,10), liming (10), or management of cover crop residues. It is well known that mulches or green manures may reduce nematode population densities and (or) benefit crop growth, but results depend on the type of mulch and duration of its use (16). Retention or removal of aboveground residues of cover crops examined here had little effect on nematode densities in a subsequent 4-month corn crop. Therefore, if tillage practices or cover crop management are changed for agronomic reasons, nontarget or unintentional effects on plant-parasitic nematodes should not be a concern.

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