Journal of Nematology 21(4):462–471. 1989.

Effects and Dynamics of a Nematode Community on Maize[1]

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Abstract: Relationships between nematode density and yield and between final and preplant population levels were examined in small maize plots on sandy soils in north-central Florida. Plant-parasitic nematodes present in the community included *Belonolaimus longicaudatus, Criconemella sphaerocephala, Meloidogyne incognita, Paratrichodorus minor, Pratylenchus brachyurus,* and a *Xiphinema* sp. Plant growth—including stand count, grain yield, stalk weight, and size of young plants—often was inversely correlated ($P \leq 0.05$) with densities of *B. longicaudatus* and occasionally with *P. brachyurus,* but not with densities of other species or with a range of soil variables. More severe losses in grain yields from *B. longicaudatus* occurred in 1987 than in 1988, although mean preplant nematode densities in February were similar in both years (4.4 vs. 3.9/100 cm^3 soil). Final population densities of most nematode species were linearly related ($P \leq 0.05$) to densities measured at planting or earlier. These relationships were stronger (higher r^2) with the ectoparasites *B. longicaudatus* and *C. sphaerocephala* than with the endoparasites *M. incognita* and *P. brachyurus.* No significant correlations were found between population densities of different nematode species.

Key words: *Belonolaimus longicaudatus,* corn, *Criconemella sphaerocephala,* damage function, lesion nematode, maize, *Meloidogyne incognita,* nematode community, population dynamics, *Pratylenchus brachyurus,* ring nematode, root-knot nematode, sting nematode, *Zea mays.*

In the southeastern United States, many species of plant-parasitic nematodes usually coexist in maize fields (2,9,17). Damage to maize is attributed to several members of this community, including species of *Belonolaimus, Meloidogyne, Paratrichodorus,* and *Pratylenchus* (14). Species of *Criconemella* and *Xiphinema* are frequent associates of maize, but their pathogenicity to the crop has not been established (14). The effects of polyspecific nematode communities on maize production are largely unknown (14). In one study (16) yield of maize was related inversely to combined population densities of *Pratylenchus* spp. and *Hoplolaimus galeatus* (Cobb) Sher. Furthermore, until recently (15) little data existed on the population dynamics of polyspecific nematode communities in maize fields.

The objectives of this study were to determine the effect of each member of a nematode community on yield of maize and to describe the dynamics and rate of growth of each species on the crop.

Received for publication 24 January 1989.

[1] Florida Agricultural Experiment Station Journal Series No. 9637. Supported in part by USDA Competitive Grant #86-CRCR-1-1971.

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The authors thank Tom Hewlett, Charlotte Zunker, Paul Ruppert, Reggie Wilcox, Jeff Simmons, Philip Cooke, and John Kiefer for technical assistance.

Materials and Methods

In October 1986, following cultivation of a maize (*Zea mays* L.) crop, 16 3-m-square plots were established in two adjacent 0.5-ha sites (eight plots per site) with similar cropping histories at the University of Florida Agronomy Farm near Gainesville. When considered together, these plots provided a range in naturally occurring populations of *Belonolaimus longicaudatus* Rau, *Meloidogyne incognita* (Kofoid & White) Chitwood, *Pratylenchus brachyurus* (Godfrey) Filipjev & Stekhoven, *Criconemella sphaerocephala* (Taylor) Luc & Raski, *Paratrichodorus minor* (Colbran) Siddiqi, and *Xiphinema* sp. (close to *X. floridae* Lamberti & Bleve-Zacheo).

On 31 October 1986 a cover crop of hairy vetch (*Vicia villosa* Roth) was planted on half of each 0.5-ha site in 15-cm rows at a rate of 68 kg seed/ha. Eight plots were located within the planted area. On 7 November the remaining area, containing the other eight plots, received rye (*Secale cereale* L. cv. Wrens Abruzzi) at 50 kg seed/ha. Cover crops were mowed and the plots were disked in early February 1987 and plowed under on 25 February. On 10 March, 560 kg 5-10-15 (N-P-K)/ha and the herbicides atrazine (1.7 kg a.i./ha) and butylate (4.7 liters a.i./ha) were applied and incorporated.

TABLE 1. Yields and other plant data from maize plots over two seasons.

Variable	1987 Mean	1987 Range	1988 Mean	1988 Range
Yield (kg/ha)	3,921	811–7,372	5,491	2,459–11,028
Stand count at harvest (plants/6 m)	17.9	3–30	22.6	16–29
Dry stalk weight at harvest (kg/6 m)	2.0	0.2–4.7	1.9	0.2–2.9
Dry root weight, April (g/plant)	0.19	0.06–0.49	0.22	0.07–0.60
Dry top weight, April (g/plant)	0.16	0.06–0.28	0.80	0.18–1.8
Dry root weight, May (g/plant)	2.0	0.2–6.8	1.6	0.46–2.9
Dry top weight, May (g/plant)	5.5	0.1–20.3	13.6	1.6–32

Data are means and ranges over 16 plots in each season.

The maize hybrid 'Pioneer X304C' was seeded 13 cm apart in 0.91-m rows on 17 March. Plots were cultivated on 21 April when 5.3 g NH_4NO_3/m of row and 3.4 g K_2SO_4/m were applied. Plots were irrigated as needed to supplement natural rainfall and were harvested on 25 August, 161 days after planting.

During the 1987–88 season, planting practices and cultivars were similar except that all cover crops were planted on 12 November 1987 and maize was harvested on 10 August 1988. In 1988 maize was planted in 0.76-m rows and the herbicide cyanazine (1.3 kg a.i./ha) was applied on 29 March. Rates of postplant fertilizers were 7.7 g NH_4NO_3/m and 8.6 g K_2SO_4/m.

Soil samples were collected from each plot eight times during each cropping season: early November at planting of winter cover crops, February before disking of cover crops, at planting of the maize crop, and five samples at monthly intervals thereafter, ending with the fifth sample at harvest. Individual samples consisted of 12 cores collected in a stratified random pattern with a sampling cone (4) 20 cm deep. Three replicate samples were collected from each plot at the November, February, maize planting, and harvest samples. The four monthly samples between maize planting and harvest consisted of single samples collected in the rhizosphere of the plants in each plot. Because each plot accommodated four rows of maize, the 12 rhizosphere cores were taken only from the outside two rows in each plot to minimize disturbance of the center rows. Nematodes were extracted from a 100-cm^3 portion of each sample with a modified sieving–centrifugation technique (8).

Sand, silt, and clay content of soil samples collected at planting were determined by the Bouyoucos (1) hydrometer method. Organic matter and a range of fertility analyses were performed with standard methods (18) on these samples by the University of Florida Extension Soil Testing Laboratory.

Harvest data were collected from the two center rows in each plot. Grain yield is reported as shelled maize at 15.5% moisture. Stalk weights and stand counts were also determined for the two 3-m rows harvested in each plot. In addition, four whole plants were collected per plot 1 and 2 months after planting from 3 m of row adjacent to each plot, thereby avoiding thinning of plants within the plot. Three of these were used for weight measurements and extraction of nematodes from the roots. Nematodes were extracted from root samples by chopping roots in a blender and incubating on Baermann trays for 48 hours. The fourth plant was used for dry weight conversions, after drying at 80 C to constant weight.

All nematode densities (per 100 cm^3 soil) were transformed by $\log_2$ (density + 1) before data analysis. Preliminary analyses revealed more consistent significant relationships with the transformed densities than with the raw nematode counts. For each season, Pearson product-moment correlation coefficients (21) were computed between all plant data and all nematode and

TABLE 2. Nematode population densities in maize plots over two seasons.

	Nematodes/100 cm³ soil							
	Nov.	Feb.	Mar.	Apr.	May	June	July	Aug.
1986–87								
Belonolaimus longicaudatus	1.3 (0–6)	4.4 (0–25)	0.9 (0–6)	4.7 (0–22)	2.1 (0–9)	15.6 (0–100)	3.4 (0–10)	2.6 (0–15)
Criconemella sphaerocephala	31.2 (6–101)	46.7 (0–173)	44.8 (0–186)	46.3 (5–143)	53.5 (2–284)	98.0 (4–479)	80.0 (0–423)	91.8 (0–419)
Meloidogyne incognita	14.4 (0–110)	6.6 (0–59)	3.1 (0–21)	11.7 (0–88)	0.5 (0–4)	9.5 (0–81)	101.9 (0–856)	16.7 (0–245)
Paratrichodorus minor	1.7 (0–4)	0	0	0.1 (0–1)	0	1.1 (0–8)	1.7 (0–4)	1.2 (0–6)
Pratylenchus brachyurus	75.8 (10–194)	55.8 (5–134)	15.6 (1–38)	16.2 (0–52)	10.9 (0–37)	13.5 (2–38)	75.1 (9–240)	102.7 (14–276)
Xiphinema sp.	0	0	1.9 (0–18)	1.9 (0–25)	1.0 (0–7)	0.6 (0–6)	0.8 (0–13)	0.3 (0–3)
P. brachyurus†	—	—	—	14 (0–50)	20 (0–86)	12 (1–50)	112 (3–616)	295 (41–757)
1987–88								
Belonolaimus longicaudatus	6.4 (0–31)	3.9 (0–13)	6.9 (0–30)	3.2 (0–16)	2.8 (0–8)	23.2 (0–107)	14.4 (0–47)	11.4 (0–63)
Criconemella sphaerocephala	62.0 (2–226)	91.3 (5–426)	89.5 (3–525)	62.2 (4–242)	105.8 (1–505)	79.4 (1–294)	287.8 (5–1,132)	161.8 (10–645)
Meloidogyne incognita	4.3 (0–49)	9.1 (0–91)	0.4 (0–2)	0.5 (0–3)	1.1 (0–8)	20.6 (0–149)	53.4 (0–266)	48.3 (0–356)
Paratrichodorus minor	0.1 (0–1)	0.1 (0–1)	0	0.7 (0–3)	1.1 (0–6)	0	0	0
Pratylenchus brachyurus	84.1 (3–340)	63.8 (9–159)	25.8 (3–48)	35.9 (4–132)	24.2 (4–74)	5.8 (1–42)	61.9 (14–163)	26.3 (5–69)
Xiphinema sp.	0.2 (0–2)	1.8 (0–24)	1.6 (0–12)	0	0.6 (0–5)	0	0	0
P. brachyurus†	—	—	—	2 (0–8)	9 (1–36)	—	203 (2–1,600)	808 (28–3,200)

Data are means and ranges (in parentheses) from 16 plots on each sampling date.
† Population density per gram dry weight of root. Dashes indicate root populations not measured.

TABLE 3. Correlation coefficients between maize data for a given season and log_2-transformed *Belonolaimus longicaudatus* densities at selected times during that season.

	Stand count	Yield (kg/ha)	Dry stalk weight	Dry top weight		Dry root weight	
				April	May	April	May
				1986–87			
Nov.	−0.65**	−0.60*	−0.55*	NS	−0.55*	NS	−0.57*
Feb.	−0.76***	−0.78***	−0.52*	−0.46	−0.66**	NS	−0.58*
Mar.	−0.62**	−0.61*	NS	NS	−0.62*	NS	−0.59*
Apr.	−0.68**	−0.57*	NS	NS	−0.67**	NS	−0.71**
Apr.†	−0.70**	−0.70**	NS	NS	−0.73**	NS	−0.68**
May	NS	NS	NS	NS	−0.53*	−0.40	−0.50*
June	−0.59*	−0.59*	NS	NS	−0.71**	NS	−0.61*
July	−0.76***	−0.72**	−0.48	NS	−0.76***	NS	−0.68**
Aug.	−0.89***	−0.83***	−0.67**	NS	−0.70**	NS	−0.60*
				1987–88			
Aug.	NS	NS	−0.48	−0.70**	−0.70**	NS	NS
Nov.	NS	NS	−0.76***	−0.65**	−0.89***	NS	−0.43
Feb.	NS	NS	−0.78***	−0.71**	−0.89***	NS	−0.49
Mar.	−0.45	NS	−0.81***	−0.69**	−0.86***	NS	−0.48
Apr.	−0.48	−0.53*	−0.86***	−0.73**	−0.83***	NS	−0.48
Apr.†	−0.43	−0.56*	−0.70**	−0.74**	−0.71**	NS	NS
May	−0.46	NS	−0.82***	−0.72**	−0.86***	NS	−0.46
June	NS	NS	−0.79***	−0.70**	−0.85***	NS	−0.56*
July	NS	NS	−0.69**	−0.64**	−0.80***	NS	NS
Aug.	−0.58*	−0.49	−0.86***	−0.70**	−0.88***	NS	−0.55*

Correlation coefficients for 16 observations. Asterisks denote significance at $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***). Coefficients significant at $P \leq 0.10$ are unmarked. NS = not significant.
† *B. longicaudatus* density per gram dry weight of root.

soil data. Correlation coefficients also were calculated between final population densities (Pf) of each nematode and densities of every species in earlier samples. Unless stated otherwise, correlations discussed in the text are significant at $P \leq 0.05$. Critical relationships involving preplant nematode densities were inspected graphically and were further examined by linear, quadratic, and (or) multiple regression analyses on nematode densities. All such data analyses were performed with the Statistical Analysis System (7). Selected relationships between yield and untransformed preplant densities were further examined with a computer program (3) to determine the best fit to Seinhorst's (19) equation.

Results and Discussion

Effect of nematodes on maize yields: Wide ranges in yield and other plant data occurred over the 16 maize plots in each season (Table 1). A preliminary analysis of variance performed on plant measurements revealed no significant effects ($P \leq 0.05$) from winter cover crops, suggesting that these ranges were caused by other factors.

Over all plots, soil pH averaged 6.1 (range: 5.6–6.5); soil organic matter, 1.2% (0.9–1.8); sand, 95.5% (93.0–98.0); silt, 2.0% (0.5–4.5); clay, 2.5% (1.5–3.0); P, 97 ppm (56–148); K, 67 ppm (44–124); Mg, 46 ppm (28–76); Ca, 344 ppm (212–548); NO_3, 6.9 ppm (4.8–9.0); and NH_4, 3.8 ppm (1.8–5.0). None of these factors was correlated with yield or other plant data. Such factors are known to influence plant yield and expression of nematode damage (6). A recent example demonstrates the effect of a range of sand content as well as nematode density on host yield (11). Ranges of these factors here, however, were probably too narrow to show much effect across the 16 test plots.

Relatively wide ranges in nematode population densities occurred in the plots during each season (Table 2). A few individ-

TABLE 4. Correlation coefficients between plant data for a given season and $\log_2$-transformed *Pratylenchus brachyurus* densities at selected times during that season.

	Stand count	Yield (kg/ha)	Dry stalk weight	Dry top weight		Dry root weight	
				April	May	April	May
				1986–87			
Nov.	NS	−0.46	NS	NS	NS	NS	NS
Feb.	NS	−0.54*	NS	NS	NS	NS	NS
Mar.	NS	−0.47	NS	−0.48	−0.62**	NS	−0.64**
Apr.	NS	NS	NS	NS	NS	NS	NS
Apr.†	−0.49	−0.73**	NS	−0.48	−0.70**	−0.48	−0.54*
May	NS	NS	NS	NS	NS	NS	NS
May†	NS	−0.50	−0.43	−0.60*	−0.63**	NS	−0.70**
June	−0.55*	−0.64**	−0.51*	NS	−0.57*	NS	−0.47
June†	NS	NS	NS	NS	NS	NS	NS
July	NS	NS	NS	NS	NS	NS	NS
July†	0.49	NS	NS	NS	NS	NS	NS
Aug.	NS	NS	NS	NS	NS	NS	NS
Aug.†	NS	NS	NS	NS	NS	NS	NS
				1987–88			
Aug.	NS	NS	NS	−0.60*	NS	NS	NS
Nov.	−0.57*	−0.63**	−0.57*	−0.54*	NS	NS	NS
Feb.	NS	NS	NS	−0.48	NS	NS	NS
Mar.	NS	NS	NS	−0.46	−0.47	NS	NS
Apr.	NS	NS	−0.46	NS	−0.50	NS	NS
Apr.†	−0.45	NS	NS	NS	NS	NS	NS
May	NS	NS	−0.51*	−0.58*	−0.58*	NS	−0.45
May†	0.49	NS	0.57*	0.50*	0.49	NS	NS
June	NS	NS	NS	NS	NS	NS	NS
July	NS	NS	NS	−0.61*	−0.44	−0.52*	NS
July†	NS	NS	−0.50	−0.43	−0.54*	NS	NS
Aug.	NS	NS	NS	NS	0.55*	NS	0.47
Aug.†	NS	NS	0.51*	NS	NS	NS	NS

Correlation coefficients for 16 observations. Asterisks denote significance at $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***). Coefficients significant at $P \leq 0.10$ are unmarked. NS = not significant.
† *P. brachyurus* density per gram dry weight of root.

uals of a *Hoplolaimus* sp. also were found. In addition, a few juveniles of *M. incognita* were extracted from root incubations late in the 1986–87 season. A mean density of 15 *B. longicaudatus*/g dry weight of root (range: 0–111) was collected from root incubations in April 1987, whereas 62/g dry weight of root (range: 0–415) were extracted in April 1988. *B. longicaudatus* also occurred in lower densities in roots in May (mean: 4.9/g dry weight) and June (mean: 1.7/g dry weight) of 1988 but was absent at other times. This recovery of *B. longicaudatus* from root samples was surprising but was noticed previously on citrus (10). Closer examination revealed that the nematode had not entered roots, nor was it bound to the roots by stylet penetration, but its long body was intertwined among the root hairs.

In each season, plant data showed numerous correlations with nematode densities, particularly *B. longicaudatus* densities measured at various times during the season (Table 3). Yield of maize in 1987 showed negative correlations with population densities measured at most times during or before the growing season. Such correlations with harvest data were less frequent in 1988; however, more consistent correlations between *B. longicaudatus* densities and weight of young plants were observed in 1988 than in 1987. These relationships between density and early season growth were more apparent with top weight than with root weight. Top weight

TABLE 5. Summary of correlations and linear regression equations for relationships between maize yield data at harvest and nematode densities at, or before, planting for two seasons.

Dependent variable (y)	Independent variable (x)†	Coefficient of determination (r^2)	Regression equation‡
	1986–87		
Stand count (plants/6 m)	Bl, Nov.	0.42**	y = 23.2 − 5.84x
	Bl, Feb.	0.57***	y = 23.4 − 3.83x
	Bl, Mar.	0.39**	y = 21.7 − 6.26x
	Pb, Nov.	NS	—
	Pb, Feb.	NS	—
	Pb, Mar.	NS	—
Yield (kg/ha)	Bl, Nov.	0.36*	y = 5,254 − 1,465x
	Bl, Feb.	0.62***	y = 5,476 − 1,075x
	Bl, Mar.	0.37*	y = 4,940 − 1,652x
	Pb, Nov.	0.21	—
	Pb, Feb.	0.29*	y = 9,361 − 999x
	Pb, Mar.	0.22	—
Dry stalk weight (kg/6 m)	Bl, Nov.	0.30*	y = 2.65 − 0.72x
	Bl, Feb.	0.27*	y = 2.56 − 0.39x
	Bl, Mar.	NS	—
	Pb, Nov.	NS	—
	Pb, Feb.	NS	—
	Pb, Mar.	NS	—
	1987–88		
Stand count (plants/6 m)	Bl, Nov.	NS	—
	Bl, Feb.	NS	—
	Bl, Mar.	0.20	—
	Pb, Nov.	0.32*	y = 30.9 − 1.45x
	Pb, Feb.	NS	—
	Pb, Mar.	NS	—
Yield (kg/ha)	Bl, Nov.	NS	—
	Bl, Feb.	NS	—
	Bl, Mar.	NS	—
	Pb, Nov.	0.40**	y = 10,571 − 886x§
	Pb, Feb.	NS	—
	Pb, Mar.	NS	—
Dry stalk weight (kg/6 m)	Bl, Nov.	0.57***	y = 2.49 − 0.33x
	Bl, Feb.	0.62***	y = 2.46 − 0.39x
	Bl, Mar.	0.66***	y = 2.53 − 0.34x
	Pb, Nov.	0.32*	y = 3.46 − 0.28x
	Pb, Feb.	NS	—
	Pb, Mar.	NS	—

Asterisks denote significance at $P \leq 0.05$ (*), $P \leq 0.01$ (**), and $P \leq 0.001$ (***). Coefficients significant at $P \leq 0.10$ are unmarked. NS = not significant.

† Log_2 of population density/100 cm^3 soil of *Belonolaimus longicaudatus* (Bl) or *Pratylenchus brachyurus* (Pb).

‡ Regression equations were computed only for relationships having significant ($P \leq 0.05$) correlation coefficients. Dashes indicate no equations.

§ A significant ($P \leq 0.05$) increase in r^2 from 0.40 for the linear model to 0.54 was provided by the quadratic equation $y = 4{,}439 + 1{,}787x - 260x^2$.

is easier to measure than root weight because it is difficult to dig up and retain all roots. Although a number of significant correlations were evident, early-season plant sizes were not consistent indicators of final yield. The three measurements made at harvest (stand count, yield, stalk weight) were positively correlated with each other in each season. Significant correlations of plant data with densities of *P. brachyurus* (Table 4) were less frequent and often of less magnitude than with *B. longicaudatus*, and significant correlations with densities of other species were rare.

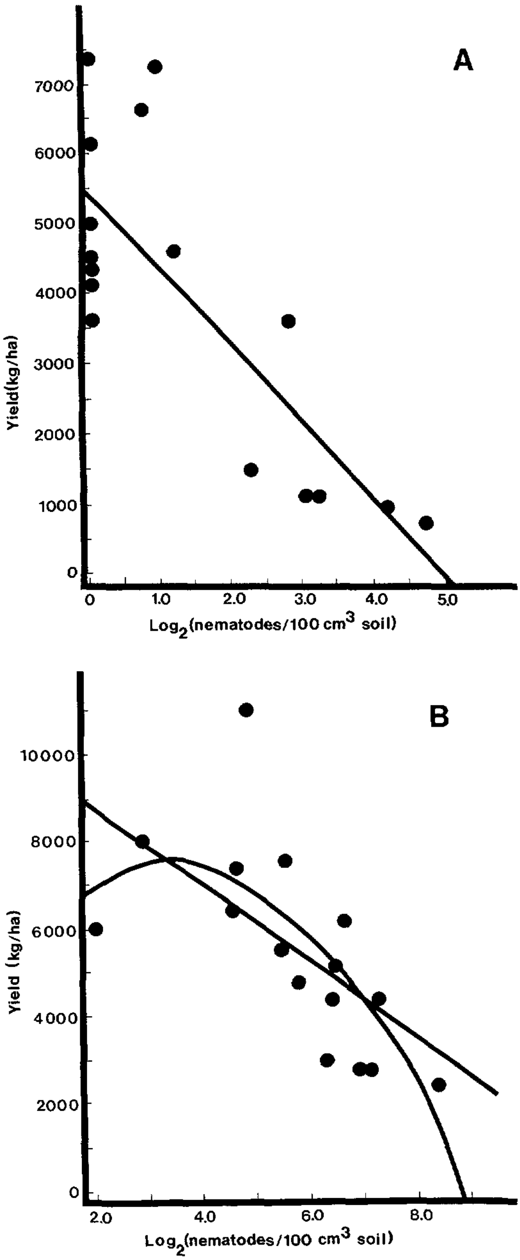

FIG. 1. Relationship between maize yield and nematode density. A) 1987 season. x = *Belonolaimus longicaudatus* density measured in February; regression equation: yield = 5,476 − 1,075x, $r^2 = 0.62$. B) 1988 season. x = *Pratylenchus brachyurus* density measured November 1987; linear regression equation: yield = 10,571 − 886x, $r^2 = 0.40$; quadratic regression equation: yield = 4,439 + 1,787x − 260x², $r^2 = 0.54$.

Yields and densities of *B. longicaudatus* throughout the season were correlated (Table 3). Previous studies (12,13) indicate that densities measured later in the growing season may sometimes show greater correlation with yield than densities measured earlier. Nevertheless, densities measured at or before planting are the most useful because they provide time to plan and implement control strategies (5,19). Relationships between three kinds of plant data collected at harvest (stand, yield, stalk weight) and nematode densities measured at planting (March) or before planting (November or February) are summarized (Table 5). Where significant correlations existed, relationships could be described by linear models relating yield to $\log_2$-transformed nematode densities (Table 5). With field data showing some degree of scatter around a line (Fig. 1A), several alternative models may describe the fit equally well but the linear model may be simplest (13). Attempts to fit data to quadratic models resulted in an improved fit (i.e., significant increase in r^2 at $P \leq 0.05$) in only one case (Fig. 1B). Models using Seinhorst's equation (19) gave consistently poorer fits (lower r^2) than the corresponding linear models. For example, the best Seinhorst equation relating maize yield in 1988 (y) to untransformed density of *P. brachyurus* in November 1987 (x) was

$$y/6{,}951 = 0.585 + 0.415(0.97)^{x-75}$$

for all x > 75 and y = 6,951 for all x ≤ 75. For this model, $r^2 = 0.19$ ($P \leq 0.10$) compared to $r^2 = 0.40$ or $r^2 = 0.54$ for the linear or quadratic models.

Attempts to relate yield data to multiple regression functions of $\log_2$-transformed densities of *B. longicaudatus* and *P. brachyurus* or to *B. longicaudatus, P. brachyurus,* and other nematodes did not provide improved fits over the linear regression models. When significant "multiple" regression models were obtained, only the term for *B. longicaudatus* gave an increase ($P \leq 0.05$) in r^2 when added as the last term of the model.

When linear relationships ($P \leq 0.05$)

TABLE 6. Summary of regression equations for relationships between final nematode densities at harvest and densities at or before planting for two growing seasons.

Dependent variable (y)† (August)	Independent variable (x)†	Coefficient of determination (r^2)		Linear regression equation	
		1986–87	1987–88	1986–87	1987–88
Bl	Bl, previous Aug.	—	0.62***	—	y = 0.72 + 1.28x
	Bl, Nov.	0.43**	0.87***	y = 0.17 + 1.00x	y = 0.13 + 1.18x
	Bl, Feb.	0.67***	0.94***	y = 0.06 + 0.70x	y = −0.02 + 1.39x
	Bl, Mar.	0.42**	0.83***	y = 0.40 + 1.10x	y = −0.04 + 1.10x
Pb	Pb, previous Aug.	—	NS	—	—
	Pb, Nov.	0.27*	NS	y = 2.49 + 0.62x	—
	Pb, Feb.	0.35*	NS	y = 2.62 + 0.66x	—
	Pb, Mar.	NS	NS	—	—
Cs	Cs, previous Aug.	—	0.71***	—	y = 2.18 + 0.75x
	Cs, Nov.	NS	0.66***	—	y = 2.86 + 0.74x
	Cs, Feb.	0.49**	0.64***	y = 3.06 + 0.61x	y = 1.86 + 0.81x
	Cs, Mar.	0.52**	0.64***	y = 3.21 + 0.60x	y = 2.06 + 0.79x
Mi	Mi, previous Aug.	—	0.28*	—	y = 1.70 + 0.79x
	Mi, Nov.	NS	0.36*	—	y = 1.53 + 1.11x
	Mi, Feb.	NS	0.38*	—	y = 1.43 + 0.98x
	Mi, Mar.	0.41**	NS‡	y = −0.30 + 1.05x	NS
X	X, Mar.	0.49§	—	y = 0.04 + 0.32x	—

Asterisks denote significance at $P \le 0.05$ (*), $P \le 0.01$ (**), and $P \le 0.001$ (***). NS = not significant. Dashes indicate not evaluated or no linear regression equation derived.

† $\log_2$ of population density/100 cm^3 soil of *Belonolaimus longicaudatus* (Bl), *Pratylenchus brachyurus* (Pb), *Criconemella sphaerocephala* (Cs), *Meloidogyne incognita* (Mi), or *Xiphinema* sp. (X).

‡ A significant ($P \le 0.05$) increase in r^2 from 0.16 to 0.68 was provided by the quadratic equation $y = 1.30 + 17.42x - 11.15x^2$.

§ A significant ($P \le 0.05$) increase in r^2 from 0.49 to 0.63 was provided by the quadratic equation $y = 0.13 - 0.34x + 0.17x^2$.

were found, there was some consistency from season to season, particularly in the relationship of stalk weight to *B. longicaudatus* density measured the previous February (Table 5). Stand counts and yields were lower in 1987 than in 1988 (Table 1) and were related ($P \le 0.05$) to *B. longicaudatus* density in the first season but not in 1988. During 1987 both stand count and yield could be related to *B. longicaudatus* density on any of the three preplant or at-plant sampling times. Density measured in early February (end of winter cover crop) was the most robust predictor of either plant yield parameter (Table 5). Damage by *B. longicaudatus* was particularly severe during 1987, with numerous seedlings killed in some plots and many seedlings exhibiting the characteristic root symptoms of *B. longicaudatus* injury (14). Yield reduction increases rapidly as population density increases and virtually no yield is predicted above densities of about 30 nematodes/100 cm^3 soil ($\log_2 32 = 5.0$, Fig. 1A). The Seinhorst curve best fitting these data ($r^2 = 0.35$) provided a tolerance limit and minimum yield of zero, consistent with our field observations of occasional dead plants in plots having high densities of *B. longicaudatus*.

Nematode population dynamics: In each season, numerous positive correlations were found between densities of *B. longicaudatus* measured at different times of the year. Positive correlations also were found frequently between *C. sphaerocephala* densities, and occasionally between *P. brachyurus* densities, between *M. incognita* densities, or between *Xiphinema* densities (data not shown). Correlations were not found between density of one species and that of another species.

For predictive purposes in planning cropping sequences, knowledge of the re-

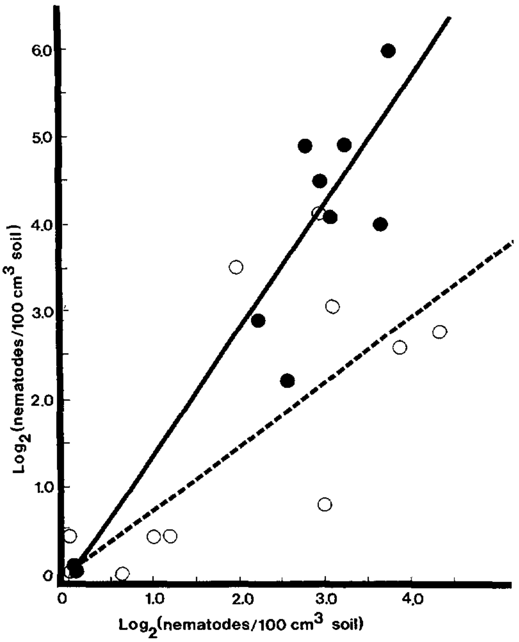

FIG. 2. Relationship between *Belonolaimus longicaudatus* density at harvest (y-axis) and preplant density (x-axis) measured in early February. Dashed line and open circles are 1987 season; regression equation: $y = 0.06 + 0.70x$, $r^2 = 0.67$. Solid lines and circles are 1988 season; regression equation: $y = -0.02 + 1.39x$, $r^2 = 0.94$.

lationship between final and initial population densities on the crop is essential (5). The opportunity existed here to relate final population (August) to each of several population densities at or before planting. A summary of these relationships for the most common nematode species present in the plots (Table 6) reveals stronger and more consistent relationships between final and initial or preplant densities for the ectoparasites *B. longicaudatus* and *C. sphaerocephala* than for the endoparasites *P. brachyurus* and *M. incognita*.

Where relationships ($P \leq 0.05$) existed between initial (Pi) and final (Pf) population densities (Table 6), they were roughly linear (Fig. 2). The leveling off of Pf at an equilibrium density as described by theoretical models (20) was not observed here. A possible explanation may be that the range of densities observed here (Table 2), while considerable over a range of field sites, did not include the extremely high Pi values needed to observe equilibrium densities of Pf. Below such extreme Pi values, the relationship between Pf and Pi could be roughly linear.

Slopes and intercepts of linear relationships between Pf and each of several initial and preplant densities were similar for a particular nematode species within a season (Table 6). For example, equations for *C. sphaerocephala* in the 1987–88 season showed a range in slopes of only 0.74–0.81 and in intercepts of 1.86–2.86. With *B. longicaudatus* the most robust indicator (highest r^2) of Pf was the population density measured in early February before planting (Table 6). The slope was greater in 1988 (1.39) than in 1987 (0.70), and this is reflected in the higher mean densities observed over the 1988 season (Table 2), although mean population densities in February were similar in both years (4.4 vs. 3.9/100 cm^3 soil).

Possibly the higher rate of increase in density of *B. longicaudatus* in 1988 could be attributed to the lower amount of plant damage (i.e., more roots available) in that season. Yet it is difficult to explain why, with similar Pi in each season, yield losses were more severe in 1987 (Tables 1, 3). More fertilizer was applied in April 1988 than in April 1987, and the early growing season was cooler in 1987. Possibly this resulted in smaller plants in April and May 1987 than in a similar period in 1988 (Table 1). This observation is supported by maximum top weights (associated with *B. longicaudatus*-free plots) of 0.28 g and 20 g in April and May of 1987, compared with 1988 values of 1.8 g and 32 g. Similar trends in mean values are less reliable, since they may reflect not only slow growth from weather and (or) fertilizer conditions, but also a considerable degree of *B. longicaudatus* damage. If plants did grow more slowly in 1987 than in 1988, it is possible that an equal number of *B. longicaudatus* associated with a smaller plant could have caused proportionately more damage in 1987.

The establishment of field plots that encompassed a range of nematode densities provided a practical means of establishing damage functions in individual seasons and in defining the magnitude of damage by *B. longicaudatus.* Although a community of nematodes pathogenic to maize were present, the damage by *B. longicaudatus* was so severe, relative to that of other species, it appears as if this is the one nematode that must be monitored and managed on maize under Florida conditions. Despite the severe damage to maize by *B. longicaudatus* here, the methods used provided no evidence for competition among members of the nematode community, a finding which is in agreement with recent results from Iowa on this host (15).

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