Seasonal Variations in Populations of Plant-Parasitic Nematodes and Vesicular-Arbuscular Mycorrhizae in Florida Field Corn

J. R. RICH, Entomology and Nematology Department, University of Florida, Agricultural Research Center, Live Oak 32060, and N. C. SCHENCK, Plant Pathology Department, University of Florida, Gainesville 32611

ABSTRACT

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Vesicular-arbuscular (VA) mycorrhizal spores and plant-parasitic nematodes were monitored every 26–42 days for 1 yr at four depths (15, 30, 45, and 60 cm) in five locations in a Florida cornfield. Nine species of plant-parasitic nematodes in seven genera were identified: *Hoplolaimus galeatus, Pratylenchus* spp., and *Belonolaimus longicaudatus* were most common, followed by *Meloidogyne incognita* and *Trichodorus christiei*. Fourteen species of VA mycorrhizal fungi in four genera were found: the most common species was *Gigaspora margarita*; *Glomus macrocarpus* var. *macrocarpus, Glomus clarus,* and *Sclerocystis sinuosa* were also found regularly. The highest numbers of plant-parasitic nematodes were recovered in September; lowest numbers were found in April and May. Mycorrhizal spores were most abundant in August and least abundant in May. More spores and nematodes were found in the first 15 cm of soil than at lower depths, but depth distribution varied somewhat in individual species of both types of organisms. Numbers of plant-parasitic nematodes and VA mycorrhizal spores varied greatly at different locations in the field. Most correlations between spore numbers and nematode populations were positive, indicating that most species of VA mycorrhizal fungi coexist on corn with most of the plant-parasitic nematode species recovered in this study.

Additional key words: population fluctuations, *Zea mays* L.

Field corn (*Zea mays* L.) is a major agronomic crop in Florida, with a value of more than $40 million in 1978 (8). Plant-parasitic nematodes are a major soilborne pest of this crop, much of the acreage requires a nematode management program that includes use of nematicides (R. A. Dunn, University of Florida, *personal communication*). However, no studies of the depth distribution or seasonal population fluctuations of nematodes in Florida soils on which field corn is grown have been reported. In the southeastern United States, nematode distribution data have been published only for a single soil depth or time of year (5,6,14,15).

Vesicular-arbuscular (VA) mycorrhizal fungi are widely associated with field corn in several areas of the world (11,16,17,24). Mycorrhizal fungi have been shown to stimulate the growth of corn in the field (15,19), which suggests that mycorrhizae may be important to field corn for normal growth. However, no studies have been conducted in Florida on the incidence of VA mycorrhizae associated with field corn.

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Fox and Spasoff (9) and Atilano et al (1) observed in greenhouse tests that plant-parasitic nematodes reduced the beneficial effects of VA mycorrhizae on tobacco and grape, respectively. Bird et al (3) and Rich and Bird (19) reported a negative correlation between nematodes and mycorrhizae on cotton in the field, and a similar relationship has been reported on soybeans in Florida (22). The objectives of this study were to determine the spatial and temporal distribution of plant-parasitic nematodes and VA mycorrhizal fungi in a north central Florida cornfield under monoculture and to relate the incidence of nematodes to the prevalence of mycorrhizae.

MATERIALS AND METHODS

A field that had been cropped to field corn for at least five consecutive years was selected for sampling. A composite analysis indicated that the soil was a coarse sand (92% sand, 5% silt, 3% clay; pH 4.6) and contained populations of several species of plant-parasitic nematodes.

Five sampling quadrates, each 4.6 × 4.6 m and 15.2 m apart, were established on the basis of preliminary assays for populations of *Hoplolaimus galeatus* (Cobb) Thorne, the most prevalent plant-parasitic nematode in soil 0–15 cm deep. Initial populations of *H. galeatus* were 10, 123, 122, 355, and 125 per 250 cm^3 of soil in sites 1–5, respectively.

Samples were collected every 26–42 days from 29 November 1977 until 11 October 1978. Five soil cores (2.8 cm in diameter) were taken in sequence from each quadrate at depths of 0–15, 15–30, 30–45, and 45–60 cm. The five cores were taken at random within each quadrate or in the corn row when this could be determined. Soil cores from each depth-quadrate location were mixed, and aliquants were removed for extraction of plant-parasitic nematodes and VA mycorrhizal spores.

Nematodes were extracted from a 250-cm^3 aliquant of soil by a modified centrifugation-sugar-flotation technique (13). Fungal spores were wet-sieved from 50 cm^3 of soil through two nested sieves with 425-μm and 90-μm openings. The contents of each sieve were dispensed in tap water into separate petri plates 150 mm in diameter. After extraction, nematodes and fungal spores were counted and identified. Spores with atypical coloration or without internal contents were not counted. For purposes of comparison, all data were adjusted to represent the population of nematodes or spores in 250 cm^3 or 1 L of soil.

In November and December, samples were collected in corn stubble of the previous crop. Before the January sampling, the corn stubble was disked twice, and by the February sampling, the land had been turned with a moldboard plow. Field corn cultivar Dekalb XL80A was planted on 23 March 1978, before the fifth sampling. Recommended cultural procedures were followed in producing the nonirrigated corn, except that no nematicides were used.

The rest of the samples were collected from growing corn or corn stubble. Before and during the last three sampling dates in August, September, and October, small amounts of Florida pusley (*Richardia scabra* L.) and crabgrass (*Digitaria sanguinalis* (L.) Scop.) were present. Physiologic grain maturity was on 13 July, and the crop was harvested 14 August.

RESULTS

The following nine species of plant-parasitic nematodes in seven genera were identified (in descending frequency of occurrence): *H. galeatus, Pratylenchus* spp. (*P. brachyurus* (Godfrey) Filip. and Sch. Stek., *P. thornei* Sher & Allen, *P. zeae* Graham), *Belonolaimus longicaudatus* Rau, *Meloidogyne incognita* (Kofoid & White) Chitwood, *Trichodorus christiei* Allen, *Criconemoides citri*

Steiner, and *Xiphinema mediterraneum* Martelli & Lamberti. Few of the last two species were found, and they were excluded from data analysis.

Fourteen species of VA mycorrhizal fungi in four genera were identified. The most common species was *Gigaspora margarita* Becker & Hall., *Glomus macrocarpus* (Tul. & Tul.) var. *macrocarpus, Glomus clarus* Nicol. & Schenck, and *Sclerocystis sinuosa* Gerd. & Bakshi were recovered with some regularity. Other species identified, in declining frequency of occurrence, were *Glomus etunicatus* Becker & Gerd., *Gigaspora heterogama* (Nicol.) Gerd. & Trappe, *Acaulospora gerdemanni* Schenck & Nicol., *Gigaspora heterogama* (Nicol.) Gerd. & Nicol., *Glomus microcarpus* Tul. & Tul., *Glomus mosseae* (Nicol. & Gerd.). Gerd. & Trappe, *Glomus fasciculatus* (Thaxt. sensu Gerd.) Gerd. & Trappe, *Gigaspora pellucida* Nicol. & Schenck, *Gigaspora niger* Redhead, and *Gigaspora rosea* Nicol. & Schenck.

At all sampling dates, plant-parasitic nematodes far outnumbered VA mycorrhizal spores. Numbers of plant-parasitic nematodes but not VA mycorrhizal spores decreased after land preparation with the moldboard plow in February (Fig. 1). Numbers of nematodes and spores did not increase until the June sampling date. From then until harvest (14 August), both nematodes and mycorrhizal spores in samples generally increased. The maximum numbers of spores and nematodes were recovered in August and September, respectively. The dominant mycorrhizal species, *Gigaspora margarita*, accounted for most of the increase in mycorrhizal spores; numbers of *Glomus* spp. spores remained relatively constant throughout the sampling period, showing only a slight increase above average in August.

M. incognita, H. galeatus, and *Pratylenchus* spp. were recovered most frequently in soil 0–15 cm deep; their numbers generally declined at lower depths (Table 1). More *B. longicaudatus* were recovered from soil 15–30 cm deep than from the other three sampling depths. Significantly more *T. christiei* occurred in soil 0–15 and 15–30 cm deep than at the lower depths.

Mycorrhizal spores of *Gigaspora margarita* and *Glomus clarus* were reovered most frequently from soil 0–15 cm deep. Numbers of *Gigaspora margarita* spores decreased significantly with depth, while *Glomus clarus* spores were more evenly distributed at the 15–30, 30–45, and 45–60 cm depths. More *Glomus macrocarpus* spores were recovered at the 30–45 and 45–60 cm depths than at the 0–15 or 15–30 cm depths.

Significant differences in the incidence of some species of both VA mycorrhizal fungi and plant-parasitic nematodes were found among the five locations in the field (Table 2). Locations 2, 4, and 5 had the highest total populations of plant-parasitic nematodes, while total VA mycorrhizal spore numbers were greatest at location 3. Spores of *Gigaspora margarita* and numbers of *B. longicaudatus* generally followed similar patterns during the sample period April–September at the five locations; both were recovered in greatest numbers at location 1 and were least abundant at

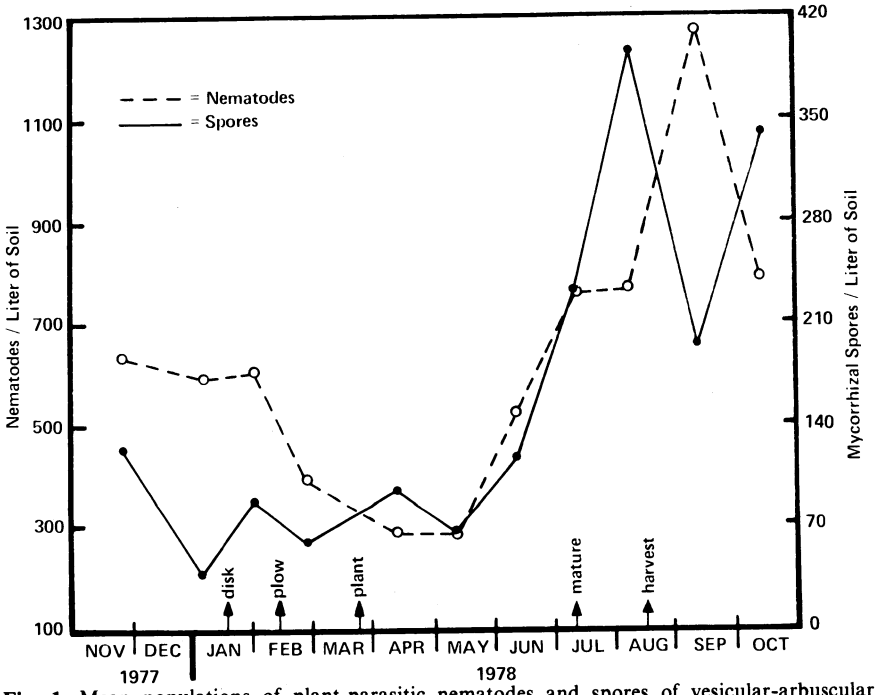

Fig. 1. Mean populations of plant-parasitic nematodes and spores of vesicular-arbuscular mycorrhizal fungi in a north Florida cornfield on 11 sample dates.

Table 1. Mean numbers of plant-parasitic nematodes and spores of mycorrhizal fungi per 250 cm^3 of soil at several depths in a Florida cornfield

Depth (cm)	Fungi[z]			Nematodes[z]				
	Gigaspora margarita	*Glomus clarus*	*Glomus macrocarpus*	*Meloidogyne incognita*	*Pratylenchus* spp.	*Belonolaimus longicaudatus*	*Hoplolaimus galeatus*	*Trichodorus christiei*
0–15	76.2 a	3.3 a	1.8 a	33.1 a	102.8 a	21.6 bc	123.9 a	12.7 a
15–30	17.7 b	0.9 a	0.7 a	9.2 b	49.4 b	42.6 a	84.6 b	14.9 a
30–45	8.5 bc	1.3 a	3.8 b	1.0 b	5.9 c	33.0 b	18.5 c	5.4 b
45–60	5.0 c	1.8 a	2.9 b	0.8 b	5.5 c	10.4 c	8.4 c	2.0 b

[z]Column means followed by the same letter are not significantly different at the 5% level, according to Duncan's multiple range test.

Table 2. Mean numbers of plant-parasitic nematodes and spores of vesicular-arbuscular mycorrhizal fungi per 250 cm^3 of soil for all samples and depths at five locations in a Florida cornfield

Location	Fungi[z]			Nematodes[z]				
	Gigaspora margarita	*Glomus clarus*	*Glomus macrocarpus*	*Meloidogyne incognita*	*Pratylenchus* spp.	*Belonolaimus longicaudatus*	*Hoplolaimus galeatus*	*Trichodorus christiei*
1	27.2 ab	2.1 a	0.3 a	6.1 a	78.9 a	41.3 a	3.7 e	9.3 b
2	27.2 ab	0.5 a	4.2 a	12.5 a	43.4 b	26.2 b	32.2 d	2.1 c
3	44.4 a	0.9 a	0.9 a	4.1 a	10.7 c	21.3 b	83.7 b	3.5 bc
4	18.2 b	3.2 a	2.4 a	16.6 a	27.8 bc	26.5 b	104.2 a	7.8 bc
5	16.7 b	1.8 a	3.4 a	15.9 a	43.8 b	19.4 b	70.4 c	20.9 a

[z]Column means followed by the same letter are not significantly different at the 5% level, according to Duncan's multiple range test.

location 5 (Fig. 2). Recoveries of *M. incognita, Pratylenchus* spp., and *Glomus macrocarpus* at the five locations also followed very similar patterns (Fig. 3).

Several simple correlations between VA mycorrhizal spore numbers and plant-parasitic nematodes were significant ($P = 0.05$). Most of those correlations were positive and occurred between *Gigaspora margarita* and the nematode species *M. incognita* in December and September; *H. galeatus* in November, December, January, April, and May; and *Pratylenchus* spp. in June, August, and September. A significant ($P < 0.05$) negative correlation occurred between *B. longicaudatus* and *Glomus clarus* in September; on several other dates, negative correlation values approached significance ($P < 0.10$).

DISCUSSION

Populations of plant-parasitic nematodes remained rather constant between November and January because of the undisturbed condition of the field and the relatively mild Florida winters (18). From February to May, however, nematode numbers declined. Because more than half of the nematodes were found in soil less than 15 cm deep, cultivation during this period probably exposed these nematodes to desiccation and temperature fluctuations, causing a reduction in numbers.

Recovery of VA mycorrhizal spores was erratic betweeen November and May, possibly because spores were sparse and unevenly distributed in the soil. However, spore numbers did not appear to fall after disking and plowing, as did nematode populations. Because no hosts were present during this period, spores were dormant.

Populations of both plant-parasitic nematodes and VA mycorrhizal spores rose by the June sampling date, 78 days after planting. This period allowed sufficient corn root growth and subsequent root invasion and multiplication by these organisms. Although grain was physiologically mature on 13 July, nematode populations continued to increase until September. Delayed nematode recovery was probably the result of *Pratylenchus* and *H. galeatus* larvae moving from the deteriorating corn roots and nematode eggs hatching in roots and soil (4). Fungal spore numbers peaked in August at the time of root senescence. Sutton and Barron (25) also noted this phenomenon with VA mycorrhizal spores on several crops in Canada.

Several VA mycorrhizal fungi have been reported to increase growth of field corn (7,10,12); however, none of these fungi were recovered in our study. Two of the most common species we found, *Gigaspora margarita* and *Glomus macrocarpus* var. *macrocarpus*, have been shown to stimulate cotton (21) and soybean (23) growth, respectively.

The varying recovery of plant-parasitic nematodes at the four depths was related both to their mode of parasitism and to the concentration of plant roots. The endoparasitic nematodes, *M. incognita* and *Pratylenchus* spp., and the semiendoparasite, *H. galeatus*, were recovered in highest numbers from soil 0–15 cm deep. Feeding sites are most concentrated at this depth (20), and nematodes inside the roots are somewhat protected from temperature and moisture extremes. The ectoparasitic nematodes *B. longicaudatus* and *T. christiei*, however, were generally recovered in greater numbers from the lower depths (primarily 15–30 cm). Because these nematodes are not protected by roots, they were located at depths less affected by environmental fluctuations (2,4).

VA mycorrhizal spore numbers generally dropped off with depth. Sutton and Barron (25) also observed a decrease in spores of VA mycorrhizal fungi in corn rhizosphere soil below a 16-cm depth in Ontario. However, the occurrence of more spores of *Glomus macrocarpus* at depths below 30 cm does not fit this generalization. Results of this study indicate that a soil sample collected only to a depth of 0–15 cm may not fully reflect the incidence or highest populations of all species of mycorrhizal fungi and plant-parasitic nematodes associated with corn roots. In the case of *T. christiei* and *B. longicaudatus*, a sampling depth of 30 cm may be useful.

Incidence of VA mycorrhizal spores and plant-parasitic nematodes varied considerably with location. These data indicate the need to take multiple samples in a field to accurately estimate the population densities of these organisms. This need has been demonstrated for plant-parasitic nematodes (2).

Our data show that mycorrhizal spore and nematode populations grew during similar time periods. This concomitant increase, reflected in several positive correlations between numbers of *Gigaspora margarita* spores and the plant-parasitic nematodes (except possibly *B. longicaudatus*) over time, indicates that these organisms coexist on field corn. In support of these data, Schenck et al (23) found that *Gigaspora margarita* interferes less with the development of root-knot nematodes on soybean than other species of mycorrhizae. Roncadori and Hussey (21) noted that the presence of *Gigaspora margarita* reduced the number of root-knot nematode eggs per gram of root but increased the total number of eggs per plant.

The low numbers of *Glomus* spp. spores we recovered precluded any meaningful correlations between plant-parasitic nematodes and *Glomus* spp. The low compatibility between *B. longicaudatus* and species of mycorrhizal fungi, though not unequivocally demonstrated in this study, was probably caused by the root-limiting parasitism of this nematode on field corn. Because VA mycorrhizal fungi are obligate symbionts, less mycorrhizal growth would be expected under conditions causing considerable root destruction. A similar situation would be expected with *T. christiei*, but the low numbers of these nematodes did not appear to limit root growth in this study.

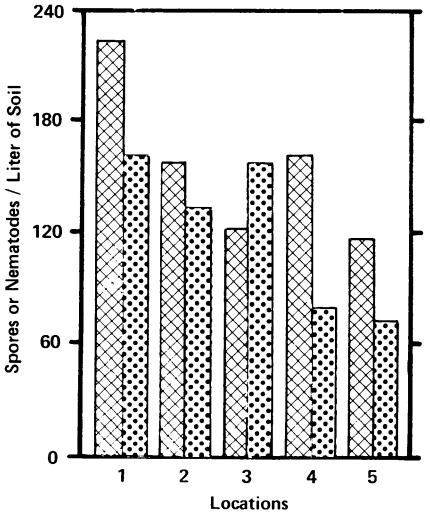

Fig. 2. Populations of *Gigaspora margarita* (dotted bars) and *Belonolaimus longicaudatus* (crosshatched bars) at five locations in a north Florida cornfield. Values are means for six sample dates (April–September 1978).

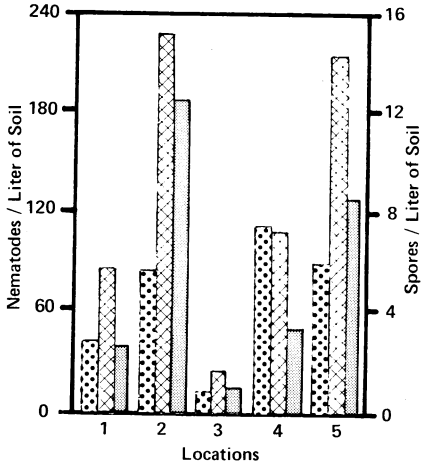

Fig. 3. Populations of *Glomus macrocarpus* (shaded bars), *Pratylenchus* spp. (crosshatched bars), and *Meloidogyne incognita* (dotted bars) at five locations in a north Florida cornfield. Values are means for six sample dates (April–September 1978).

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