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Niche Distribution of *Paratrichodorus minor* and *Belonolaimus longicaudatus* Following Fumigation on Potato and Cabbage[1]

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Abstract: An experiment was conducted to determine population changes and niche variation in the soil at two depths (0 to 20 cm and 20 to 40 cm) of *Paratrichodorus minor* and *Belonolaimus longicaudatus* populations following fumigation. Eight plots each of potato (*Solanum tuberosum*) and cabbage (*Brassica oleracea* var. *capitata*), fumigated with 1, 3-dichloropropene or nonfumigated, were established. Eight plots of sorghum-sudangrass hybrid (*Sorghum bicolor* × *S. arundinaceum* var. *sudanense*) were also used to monitor depth distribution (0 to 20 cm and 20 to 40 cm) of *B. longicaudatus* and *P. minor* following each cabbage/potato season. Soil samples were taken 0 to 20 cm and 20 to 40 cm deep during the potato/cabbage, and sorghum-sudangrass growing seasons. During the 1993–94 and 1994–95 potato/cabbage seasons, *P. minor* was found at highest numbers at 20 to 40 cm, whereas numbers of *B. longicaudatus* were highest at 0 to 20 cm. During the 1994 and 1995 sorghum-sudangrass growing seasons, *B. longicaudatus* numbers were highest at 0 to 20 cm. *Paratrichodorus minor* numbers were highest at 0 to 20 cm and at 20 to 40 cm deep in the 1994 and 1995 sorghum-sudangrass growing seasons, respectively. Reduction by soil fumigation of *B. longicaudatus* at 0 to 20 cm deep did not affect depth distribution or cause *P. minor* populations to increase in potato or cabbage plots. *Paratrichodorus minor* numbers increased at 20 to 40 cm deep in the 1994–95 cabbage season after soil fumigation.

Key words: Belonolaimus longicaudatus, Brassica oleracea, cabbage, ecology, nematode, niche depth, *Paratrichodorus minor,* potato, sampling depth, *Solanum tuberosum, Sorghum bicolor* × *S. arundinaceum* var. sudanense, sorghum-sudangrass, sting nematode, stubby root nematode.

Paratrichodorus minor (Colbran) Siddiqi and *Belonolaimus longicaudatus* Rau are among the most important nematodes parasitizing potato (*Solanum tuberosum L.*), cabbage (*Brassica oleracea* L. var. *capitata*), and sorghum (*Sorghum bicolor* L.) in northeast Florida (McSorley and Gallaher, 1991; Rhoades, 1968; Rhoades, 1976; Rhoades, 1984; Weingartner et al., 1983). Fields in northeast Florida planted with potato or cabbage during the spring are also usually planted with a sorghum-sudangrass hybrid (*Sorghum bicolor* (L.) Moench × *S. arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.) in the summer (Weingartner et al., 1993).

Paratrichodorus minor reduces potato tuber quality by transmitting the tobacco rattle virus (Walkinshaw et al., 1961). This virus causes the disease known as corky ringspot (CRS) resulting in symptoms that make the tubers unmarketable (Weingartner et al., 1983). *Belonolaimus longicaudatus* does not transmit viruses but stunts potato root growth and causes necrotic lesions on the tubers (Crow et al., 1999).

The fumigants 1, 3-dichloropropene (1, 3-D) and metam sodium are used as cost-effective management tools for most nematodes affecting potato in northeast Florida. Although soil fumigants have controlled CRS in Europe (Cooper and Thomas, 1970; Dallimore, 1972; Livingston et al., 1976; Maas, 1975), fumigation failed to control CRS and its trichodorid (*Paratrichodorus spp.* and *Trichodorus spp.*) vectors in northeast Florida (Weingartner et al., 1975a, 1975b; Weingartner et al., 1976).

After soil fumigation, trichodorid densities increased to levels exceeding those in nonfumigated plots while population densities of *B. longicaudatus* in the same plots were reduced to low levels (Brodie, 1968; Perry, 1953; Rhoades, 1968). Data from these earlier studies suggested a negative association

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between trichodorid and *B. longicaudatus* population levels.

The niche of a species in the absence of competitors from other species is its fundamental niche. However, the same species may be restricted to a realized niche (e.g., a different soil depth) in the presence of competitors (Begon et al., 1996). Competition was suggested by reports of trichodorids and *B. longicaudatus* inhabiting different niches when they occurred together. For example, on soybean (*Glycine max* (L.) Merr.) *B. longicaudatus* was predominantly found in the upper 30 cm of the soil profile, whereas trichodorids were most abundant at 15 to 45 cm deep (Brodie, 1976; McSorley and Dickson, 1990a).

The fumigation effect on concomitant populations of *B. longicaudatus* and trichodorids at various soil depths has not been studied. In fields infested with both nematodes, reduction of *B. longicaudatus* by fumigation may cause *P. minor* to increase in numbers and (or) migrate up into the unoccupied space. The objective of this research was to determine numbers of *P. minor* and *B. longicaudatus* at 0 to 20 and 20 to 40 cm deep on potato and cabbage following soil fumigation. We also present data on depth distribution of *P. minor* and *B. longicaudatus* on sorghum-sudangrass.

Materials and Methods

Experiments were established during the 1993–94 and 1994–95 winter and summer growing seasons at the University of Florida, Institute of Food and Agricultural Sciences, Research and Education Center, Yelvington Farm, Hastings, Florida. Soil texture was 95% sand, 2.0% silt, 3.0% clay, and 1.4% organic matter at 0 to 20 cm deep, and 94.0% sand, 3.6% silt, 2.4% clay, and 1.2% organic matter at 20 to 40 cm; pH 5.5 to 6.0. The soil was naturally infested with *P. minor* and *B. longicaudatus*. Potato had been grown on the site during each winter and a sorghum-sudangrass hybrid grown during the summer for at least 25 years.

Potato and cabbage: The potato 'Red La-Soda' and cabbage 'Bravo' were planted on 21 December 1993 and 23 January 1995 at a spacing of 15 cm between seed potato pieces or cabbage seedlings. The experimental design was a two-level split-plot with two nematicide treatments (fumigated with 1,3-D and nonfumigated) as the whole plot factor arranged in a randomized complete block design. Two crops (potato and cabbage) were sub-plots, and two sampling depths (0 to 20 cm and 20 to 40 cm) were sub-sub-plots. All treatment combinations were replicated eight times. An experimental unit consisted of one 10-m-long row. The fumigant 1,3-D was applied 32 cm deep with a single chisel at 56 liters/ha in row on 24 November 1993 and 16 December 1994. Standard practices for insect, disease, and weed management were used (Hochmuth et al., 1996). The experimental area was fertilized at planting with 134.5 kg N + 134.5 kg P_2O_5 + 134.5 kg K_2O/ha and side-dressed 45 days after planting with 78 kg N + 11 kg P_2O_5 + 67 kg K_2O/ha. Plots were irrigated as needed (Rogers et al., 1975).

Nematode soil samples consisted of six cores (2.5-cm diam.) taken from each subplot at 0 to 20 cm and 20 to 40 cm deep. Samples were taken on seven and five different dates in the 1993–94 and 1994–95 seasons, respectively. The six cores were mixed manually, and a 100-cm^3 subsample was removed for nematode extraction by a centrifugal-flotation technique (Jenkins, 1964). The extracted nematodes were dispersed in water in a gridded counting dish, identified, and counted.

Data were subjected to analysis of variance for a two-level split-plot design (Montgomery, 1991) using SAS (SAS Institute, Inc. Cary, NC). Mean numbers of *B. longicaudatus* and *P. minor* from nonfumigated plots were compared within each crop between soil depths of 0 to 20 cm and 20 to 40 cm with a paired *t*-test. Mean numbers of *B. longicaudatus* in soil at 0 to 20 cm and *P. minor* at 20 to 40 cm were compared within each crop between fumigated and nonfumigated plots with a paired *t*-test.

Sorghum-sudangrass: After the potato and cabbage crops were harvested, a sorghum-sudangrass hybrid was planted on 23 June 1994 and 21 June 1995. Each plot consisted of one 10-m-long row. Soil samples consisted of six cores (2.5-cm diam.) taken at 0 to 20 cm and at 20 to 40 cm on 23 June, 4 August, and 30 August during the 1994 season, and on 18 July, 18 August, and 22 September during the 1995 season. Nematode samples were processed as described previously. Mean numbers of *B. longicaudatus* and *P. minor* in soil at 0 to 20 cm and at 20 to 40 cm were compared using a paired *t*-test.

Results and Discussion

Potato and cabbage: Nematicide treatment affected ($P \leq 0.05$) *B. longicaudatus* numbers on most dates in both seasons. The abundance of both nematodes was greatly affected by sampling depth, but in opposite ways. With the exception of 25 February in the 1993–94 season, depth affected *B. longicaudatus* numbers in both seasons. Population densities were higher at 0 to 20 than at 20 to 40 cm deep on potato and cabbage on most sampling dates in the nonfumigated

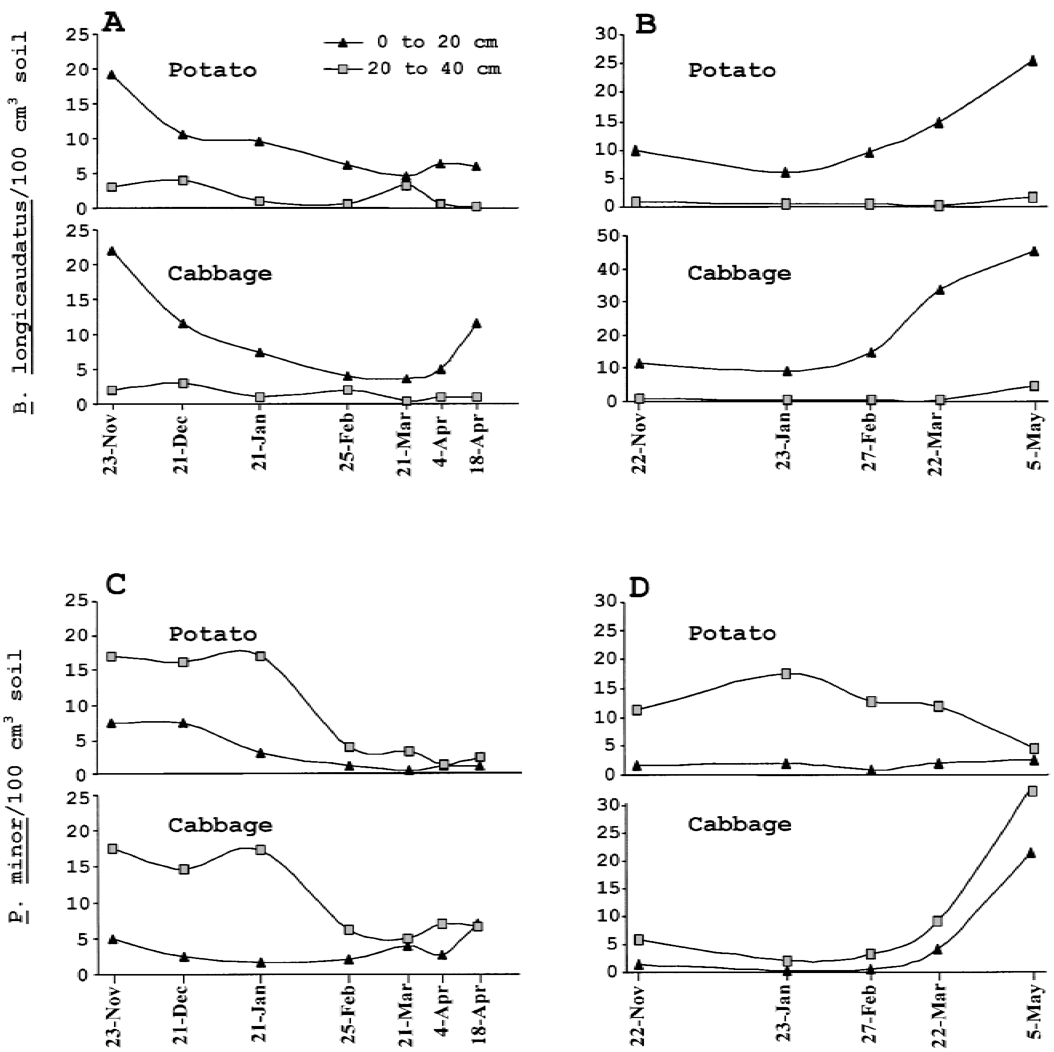

Fig. 1. Number of nematodes per 100 cm^3 of soil at 0 to 20-cm and 20 to 40-cm depths in nonfumigated plots on potato and cabbage. A) *Belonolaimus longicaudatus,* 1993–94 season. B) *B. longicaudatus,* 1994–95 season. C) *Paratrichodorus minor,* 1993–94 season. D) *P. minor,* 1994–95 season.

plots in both seasons ($P \leq 0.05$) (Fig. 1A,B). *Belonolaimus longicaudatus* numbers at 20 to 40 cm deep were low on both crops in the nonfumigated plots (≤4.4 nematodes/100 cm^3 of soil) (Fig. 1A,B). These observations agree with reports that *B. longicaudatus* was more abundant on soybean and maize fields at soil depths of 0 to 30 cm than at 30 to 45 cm (Brodie, 1976; McSorley and Dickson, 1990a, 1990b).

With the exception of 18 April in the 1993–94 season, depth affected *P. minor* numbers in both seasons. Nematode densities were higher at 20 to 40 than at 0 to 20 cm deep on most sampling dates on potato and cabbage in both seasons ($P \leq 0.05$) (Fig. 1C,D). McSorley and Dickson (1990b) reported this nematode as being most prevalent between 15 to 45 cm deep on soybean. Brodie (1976) found highest densities of *P. minor* between 15 to 30 cm deep on soybean and suggested that soil texture influenced the vertical distribution of *P. minor* as well as the distribution of other nematode genera. Since soil textures in this study were similar at both depths, it is unlikely that the depth

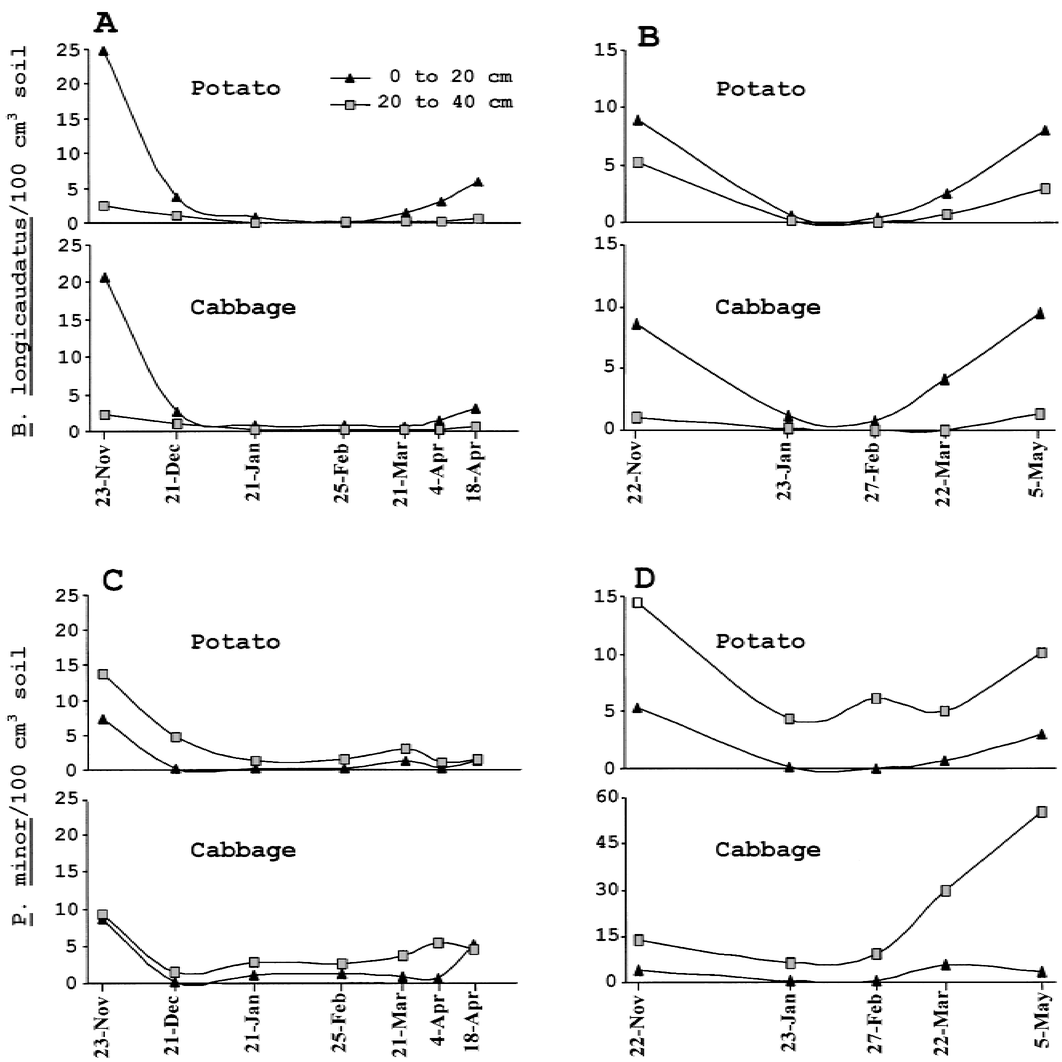

FIG. 2. Number of nematodes per 100 cm^3 of soil at 0 to 20-cm and 20 to 40-cm depths in fumigated plots on potato and cabbage. A) *Belonolaimus longicaudatus,* 1993–94 season. B) *B. longicaudatus,* 1994–95 season. C) *Paratrichodorus minor,* 1993–94 season. D) *P. minor,* 1994–95 season. Fumigant applied 24 November 1993 and 16 December 1994.

distribution of *P. minor* and *B. longicaudatus* was influenced by soil texture. This experiment indicates that *P. minor* and *B. longicaudatus* have distinctive depth preferences. Highest population densities of *B. longicaudatus* were found at 0 to 20 cm deep, whereas highest population densities of *P. minor* occurred at 20 to 40 cm deep on potato and cabbage.

There was a direct interaction between nematicide treatment and sampling depth on two dates for *B. longicaudatus* in the 1993–94 season and on all dates in the 1994–95 season ($P \leq 0.05$). Because more than 80% of the *B. longicaudatus* population densities occurred between 0 to 20 cm deep (Fig. 1A,B), possibly higher *B. longicaudatus* numbers were killed by nematicide at 0 to 20 cm than at 20 to 40 cm deep. In general, *B. longicaudatus* was reduced by nematicide treatment ($P \leq 0.05$) throughout both seasons on both crops, although some recovery was evident at the end of the 1994–95 season (Fig. 2A,B). The effect of nematicide treatment on *P. minor* varied with season and sampling date. Few instances of population reductions by nematicide were observed for *P. minor* late in the seasons. Numbers of *P. minor* were higher following fumigation on cabbage at 20 to 40 cm deep than in nonfumigated plots (Figs. 1D,2D) ($P \leq 0.05$) on May 5 in the 1994-95 season. The finding of higher numbers of *P. minor* in fumigated soil is similar to previous reports (Perry, 1953; Rhoades, 1968). However, at the depth of 0 to 20 cm, numbers of *P. minor* did not increase after soil fumigation on cabbage (Fig. 2D). This finding does not support the hypothesis that *P. minor* numbers would increase at 0 to 20 cm deep when *B. longicaudatus* populations were reduced by soil fumigation at that depth.

When crop x nematicide interactions were examined for the 1994–95 season, *P. minor* numbers were higher on cabbage than on potato in the fumigated plots ($P \leq 0.05$) (Fig. 1D). Potato is susceptible to *B. longicaudatus,* whereas cabbage is susceptible to *B. longicaudatus* and *P. minor* (Rhoades, 1968; Weingartner et al., 1983). Given this host preference, increase in numbers of *P. minor* after soil fumigation on cabbage but not on potato suggests that *P. minor* may resurge in fumigated soil in the presence of a susceptible host.

Sorghum-sudangrass: The depth distribution of *B. longicaudatus* on this crop was similar to that on potato and cabbage. Highest population densities of *B. longicaudatus* were found in the upper 0 to 20 cm of soil ($P \leq 0.05$) (Table 1). While *P. minor* population densities at different depths in the 1995 sorghum-sudangrass season were consistent with the observations during the potato and cabbage seasons (highest densities at 20 to 40 cm), findings in the 1994 season were not. With the exception of 23 June 1994, *P. minor* population densities were higher at 0 to 20 cm than at 20 to 40 cm deep in the 1994 season ($P \leq 0.05$) (Table 1). Maybe *P. minor* changed its realized niche due to subtle seasonal changes in the soil environment in this season.

The depth preferences of *B. longicaudatus* and *P. minor* were consistent during most of the seasons. Numbers of *P. minor* at 0 to 20 cm deep did not increase after *B. longicaudatus* numbers were reduced by fumigation at the same depth. The association and potential for competition between these two nematode species may be limited because their niches are separated vertically.

Sampling from 0 to 20 cm deep would estimate most of the *B. longicaudatus* numbers, while this sampling depth will miss

TABLE 1. Number of *Belonolaimus longicaudatus* and *Paratrichodorus minor* per 100 cm^3 of soil at 0 to 20 cm and 20 to 40 cm deep in nonfumigated plots on sorghum-sudangrass; 1994 and 1995 seasons.

	Nematodes per 100 cm^3 of soil			
	P. minor		*B. longicaudatus*	
Sampling date	0 to 20 cm	20 to 40 cm	0 to 20 cm	20 to 40 cm
23 June 1994	2.7	4.8	6.9*	0.1
4 Aug. 1994	35.0*	14.8	6.3*	0.1
30 Aug. 1994	20.1*	10.8	11.6*	2.0
18 July 1995	15.6	10.1	18.5*	10.0
18 Aug. 1995	9.3*	45.8	42.0	40.5
22 Sept. 1995	19.0*	38.8	22.0*	1.7

* Significantly different from densities at 20 to 40 cm ($P \leq 0.05$), according to a paired *t*-test.

more than 50% of *P. minor* numbers when sampling on potato, cabbage, and sorghum-sudangrass crops. Experiments should be conducted in the greenhouse to compare the responses between both nematodes living alone and their responses when in combination. Such experiments may provide useful clues to the effects of biotic and abiotic factors on niche differentiation of *B. longicaudatus* and *P. minor*.

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