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Effect of Cropping Regime on Populations of *Belonolaimus* sp. and *Pratylenchus scribneri* in Sandy Soil[1]

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Abstract: The host efficiencies of corn, sorghum, soybean, and wheat were compared for a Kansas population of *Belonolaimus* sp. under greenhouse conditions. In a related field study conducted in 1989 and 1990, the responses of *Belonolaimus* sp. and *Pratylenchus scribneri* populations to eight cropping regimes were monitored at depths of 0–30 and 31–60 cm in sandy soil. With the exception of alfalfa, all crop species examined supported substantial increases in populations of both nematodes. Largest nematode population increases in the field occurred in corn plots, whereas alfalfa did not allow reproduction by either species during the 2 years of observation. Soil populations of both nematodes remained at detectable levels after 2 years of fallow. The distribution of numbers of *Belonolaimus* sp. between soil depths varied with sampling date, whereas populations of *P. scribneri* were consistently concentrated in the top 30 cm of soil.

Key words: alfalfa, *Belonolaimus* sp., corn, crop rotation, fallow, *Glycine max,* lesion nematode, *Medicago sativa,* nematode, *Pratylenchus scribneri,* sorghum, *Sorghum bicolor,* soybean, sting nematode, *Triticum aestivum,* vertical distribution, wheat, *Zea mays.*

Sandy soils are common to the flood plain of the Arkansas River, which, in Kansas, stretches for more than 500 km from the southwestern to the southcentral region of the state. Crops grown in these irrigated soils, particularly corn (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), and soybean (*Glycine max* (L.) Merr.), frequently suffer serious seedling root damage caused by an undescribed species of *Belonolaimus* similar to *B. nortoni* Rau (5). Seed production can be severely impaired, and predictive models relating yield loss to soil densities of this nematode have been described for corn (15). In addition to *Belonolaimus* sp., most of these soils contain moderate to high populations of *Pratylenchus scribneri* Steiner, another important nematode pest of corn (13,16). Sorghum and soybean are also reported to sustain populations of *P. scribneri* (14).

Other standard crops for this region of Kansas include alfalfa (*Medicago sativa* L.) and wheat (*Triticum aestivum* L.). Field injury to *Belonolaimus* sp. has not been observed for either crop, but host status and susceptibility have not been adequately determined. Wheat is reported to be a host for *P. scribneri,* whereas alfalfa appears to be a nonhost (14).

Current management recommendations for nematodes in the sandy soils of Kansas rely heavily on the use of nematicides (5). Implementation of an effective cultural control program based on crop rotation offers a desirable alternative to costly chemical applications but is confounded by the wide host ranges displayed by species of *Belonolaimus* (4,11). The objectives of this study were to determine the relative host suitability of various crop species for Kansas populations of *Belonolaimus* sp. and *P. scribneri* and to examine the potential for managing these nematodes through crop rotation.

Materials and Methods

Greenhouse experiment: Pots containing 800 ml of *Belonolaimus* sp.-infested Tivoli fine sand (93% sand, 2% silt, 5% clay; pH 6.5, < 1% organic matter) were seeded on 13 June with corn cv. Pioneer 3183, sorghum cv. Pioneer 3082, soybean cv. Essex, or wheat cv. Tam 101. Initial *Belonolaimus* sp. density was determined to be 60 ± 20 nematodes per 800-ml plot. The experi-

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mental design was a randomized complete block with 12 replications. Plants were grown for 16 weeks under ambient temperatures of 30 C day and 24 C night. Three treatment blocks were randomly selected at approximately monthly intervals for measurement of nematode reproduction. Nematodes were extracted from 100-cm^3 subsamples using a modified Christie-Perry technique (1). Life-stages of *Belonolaimus* sp. were counted separately, but only total numbers of nematodes are reported.

Field experiment: The experiment was conducted during 1989–90 in a Canadian fine sandy loam (92% sand, 2% silt, 6% clay; pH 7.1, < 1% organic matter) in a commercial field near Hutchinson, Kansas, with indigenous populations of *Belonolaimus* sp. and *Pratylenchus scribneri* Steiner. Low population densities (mean < 5/100 cm^3 soil) of *Paratrichodorus minor* (Colban) Siddiqi and *Xiphinema americanum* Cobb were also present. Five continuous cropping regimes ('Buffalo' alfalfa, 'Cargill 7993' corn, 'Cargill 6670' sorghum, 'Williams 82' soybean, and fallowed soil) and three rotations (fallow–corn, soybean–corn, and corn–soybean) were established on 10 May 1989. Experimental plots consisted of four 6.1-m long rows with 75-cm spacing arranged in a randomized complete block design with four replications. Plots were re-established on 17 May 1990 in the same location.

Prior to each planting date, all plots except those seeded to alfalfa were cultivated and treated with the herbicide alachlor (3.16 liters a.i./ha; sorghum seed was treated with the seed protectant flurazole). Alfalfa plots were cultivated and treated with the herbicide DCPA (5.0 kg a.i./ha) prior to seeding in 1989. Alfalfa and soybeans received the proper *Rhizobium* spp. inoculant (Urbana Laboratories, St. Joseph, MO) at the recommended rates. Corn and sorghum plots were fertilized at planting with 110 kg/ha N (NH_4NO_3) followed by one or two midseason applications of 55 kg/ha N for sorghum or corn, respectively. Plots were irrigated and hand weeded as necessary.

Nematode population densities were monitored at two soil depths and at approximately monthly intervals during both growing seasons. On each sampling date, four 2-cm-d soil cores were composited for the 0–30 and 31–60 cm depths from the two center rows of each experimental plot. Nematodes were extracted from 100-cm^3 subsamples as described for the greenhouse study. Midseason root samples were also collected in both years, and *P. scribneri* populations were extracted as described by Georgi et al. (3).

Data analysis: Nematode population data were log-transformed ($\log_2 [x + 1]$) prior to analysis. A repeated-measures analysis of variance was applied to sampling date and depth effects (9,12). Main effect and interaction means were compared using appropriate LSD values (9).

RESULTS

Greenhouse experiment: Differences in reproduction of *Belonolaimus* sp. were not detected among crop species until 48 days after planting (Table 1). Populations increased on all four crops, but reproduction on wheat and sorghum was greater ($P \leq 0.05$) than that observed on corn at 48 and 82 days after planting, respectively. The largest increases in nematode populations on corn and sorghum occurred at 82 days, whereas maximum populations on soybean and wheat were observed during the first 2 months of the experiment. Numbers of second-stage juveniles (J2) remained high (greater than 20% of the total population) on sorghum, soybean, and wheat through Day 82 but contributed significantly to populations on corn only at Day 24, when 36% of the population were J2. By Day 112, only sorghum retained higher numbers of *Belonolaimus* sp. than at planting.

Field experiment: Significant interactions ($P \leq 0.05$) between cropping regime and date and between cropping regime and depth were observed for soil populations of *Belonolaimus* sp. and *P. scribneri* in both years (Table 2). Numbers of *Belonolaimus* sp. increased only in plots planted to corn or sorghum, whereas populations in fallowed plots and in plots planted to alfalfa

TABLE 1. Host suitability of four crops for a Kansas population of *Belonolaimus* sp. under greenhouse conditions.

Crop	Reproductive factor (Pf/Pi) Day 24	Day 48	Day 82	Day 112
Corn	1.6 a	0.5 b	2.4 b	0.3 a
Sorghum	4.9 a	3.5 ab	9.4 a	2.1 a
Soybean	4.7 a	2.3 ab	0.9 b	1.0 a
Wheat	1.2 a	5.8 a	2.4 b	0.5 a

Means within a column followed by the same letter are not significantly different according to Fisher's LSD procedure ($P \leq 0.05$).

or soybean declined rapidly and remained low during the 2-year period (Figs. 1, 2). A trend of increasing *Belonolaimus* sp. density was observed for soybeans following corn in 1990, however (Fig. 2). Numbers of this nematode had declined from peak levels in all plots by the end of both growing seasons. Typical patterns of *Belonolaimus*-induced stunting and root injury (10) were observed for corn, sorghum, and soybean during 1989 and 1990 but were never observed for alfalfa.

Densities of *Belonolaimus* sp. tended to be higher in the top 30 cm of soil for plots that retained significant population levels. However, a significant interaction also occurred between depth and sampling date in both years of the study (Table 2). In 1989, this was clearly due to a general decline in nematode populations in the top 30 cm, whereas numbers below that depth remained low throughout the season. A more interesting trend was observed for 1990 and is represented by the population response in plots planted to continuous corn (Fig. 3). Numbers of nematodes were not significantly different between depths at planting, but as *Belonolaimus* sp. populations increased in the top 30 cm of soil, the nematode population temporarily dropped to undetectable levels below 30 cm. After midseason, population increase occurred only below the 30-cm depth, although reproduction (as measured by the number of J2 recovered) was consistent between depths.

The response of *P. scribneri* populations to cropping regime was consistent for both years of the study, so only data from 1990 are presented (Table 3). Soil populations remained low in all plots until near the end of the growing season, when nematodes began to leave senescent roots. Midseason root and final soil nematode densities were highest in corn plots and lowest in alfalfa plots (Table 3). Sorghum roots exhibited significantly lower nematode densities than did corn roots, whereas soybean roots were intermediate. Numbers of *P. scribneri* in the soil under alfalfa were not different ($P \leq 0.05$) from those in fallowed plots at the end of the season. In plots where reproduction occurred, nematode densities were

TABLE 2. Analysis of variance for cropping regime, depth, and time effects on soil population trends for *Belonolaimus* sp. and *Pratylenchus scribneri*.

Source of variation	Mean squares: *Belonolaimus* sp. 1989	*Belonolaimus* sp. 1990	*P. scribneri* 1989	*P. scribneri* 1990
Block	0.56	2.50	31.33*	2.23
Cropping regime (Cr)	25.83*	25.70*	27.24	59.06*
Error A	2.09	5.57	8.88	4.76
Date	39.13*	29.55*	32.36*	145.97*
Cr × date	4.16*	2.28*	19.58*	7.36*
Error B	2.07	1.42	2.67	1.79
Depth	316.44*	60.31*	34.75*	12.84*
Cr × depth	7.28*	2.72*	7.20*	3.62*
Date × depth	16.70*	2.69*	2.78	2.86
Cr × date × depth	1.78	0.94	1.80	1.27
Error C	1.22	1.06	2.22	1.30

* $P \leq 0.05$.

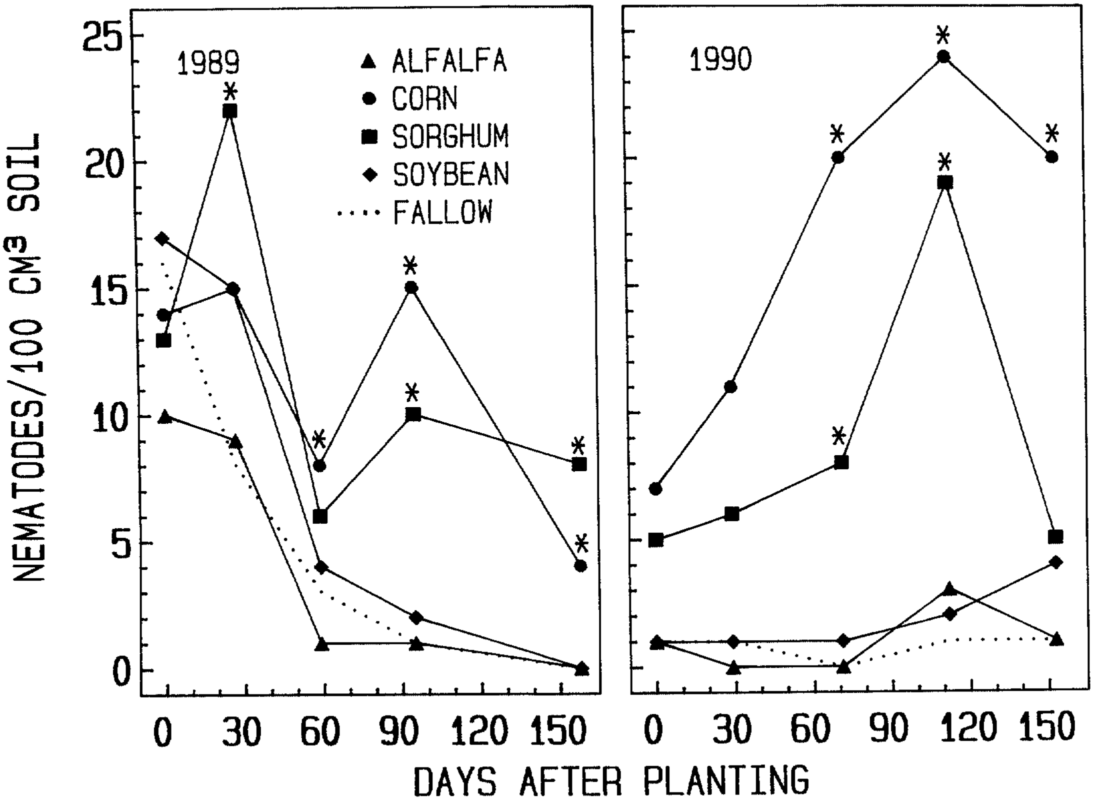

FIG. 1. Response of *Belonolaimus* sp. populations to five continuous cropping regimes during 1989–1990. Data points are means of four replications and two soil depths. Asterisks indicate populations greater ($P \leq 0.05$) than those in fallowed soil based on least significant differences for cropping regime within sampling date.

significantly higher in the top 30 cm of soil where roots were concentrated. Approximately 70% of the *P. scribneri* soil population was recovered from this zone.

Populations of *P. minor* and *X. americanum* remained low (mean < 5/100 cm^3 soil) in all plots, but survival occurred predominately on corn and sorghum at lower and upper sampling depths, respectively.

DISCUSSION

All crop species examined in this study, except alfalfa, supported substantial levels of reproduction by Kansas populations of *Belonolaimus* sp. and *P. scribneri*. In the greenhouse, sorghum was a more suitable host for *Belonolaimus* sp. than was corn, soybeans, or wheat, apparently because of the volume of root growth. Sorghum has been documented to possess twice as many secondary roots as corn at any given growth stage (2). Moreover, perennial sorghums show a minimal decrease in root density following reproductive maturity, whereas roots of senescent annuals decline rapidly (2). Root growth and severity of initial root damage are factors reported to influence population trends for *Belonolaimus* species (4). In the field, corn and sorghum appeared to be equally suitable hosts for *Belonolaimus* sp., but corn was the better host for *P. scribneri*. Alfalfa was not a suitable host for either nematode, whereas soybean was intermediate in host efficiency for both nematode species. The rapid decline of *Belonolaimus* sp. densities in soybean plots during 1989 coincided with observations of extensive initial destruction of feeding sites (root tips) and a relatively lower abundance of secondary root growth compared to corn

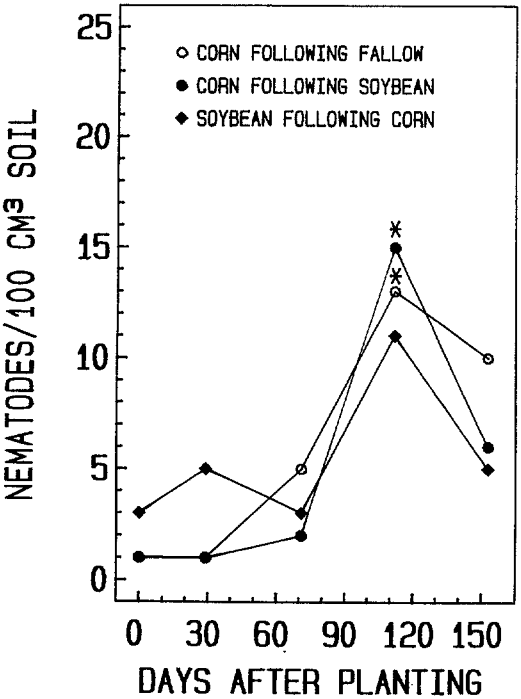

FIG. 2. Response of *Belonolaimus* sp. populations to three rotation regimes during 1990. Data points are means of four replications and two soil depths. Asterisks indicate populations greater ($P \leq 0.05$) than those in fallowed soil based on least significant differences for cropping regime within sampling date.

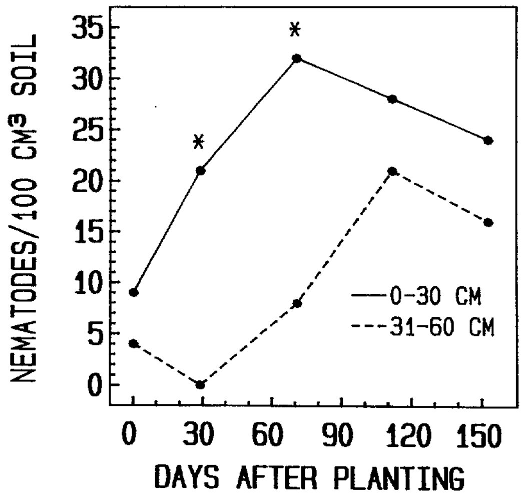

FIG. 3. Population trends for *Belonolaimus* sp. at two soil depths in corn plots during 1990. Data points are means of four replications. Asterisks indicate differences ($P \leq 0.05$) between depths based on least significant differences for depth within date.

and sorghum. Some reproduction did occur in soybean plots during 1990, when initial nematode densities were lower. Recent research has suggested that population growth for another species of *Belonolaimus* is density-dependent on soybean but density-independent on corn at similar population ranges (6,7). The ability of soybean plants to compensate for *Belonolaimus* injury, as reported by McSorley and Dickson (7), was also observed in this study.

TABLE 3. Effect of eight cropping regimes on midseason root and harvest soil densities of *Pratylenchus scribneri* during 1990.

Cropping regime	Number of *P. scribneri* Per g root	Per 100 cm³ soil
Alfalfa	2 d	5 b
Continuous corn	335 ab	126 a
Corn following fallow	368 ab	174 a
Corn following soybean	638 a	106 a
Continuous fallow	—	4 b
Continuous sorghum	63 c	43 a
Soybean following corn	72 bc	63 a
Continuous soybean	156 bc	36 a

Means within a column followed by the same letter are not significantly different according to Fisher's LSD procedure ($P \leq 0.05$).

Populations of *Belonolaimus* sp. and *P. scribneri* declined rapidly in fallowed plots, but both species were still detectable after 2 years without a cultivated crop. When corn, a host for both species, followed 1 year of fallow, these nematodes attained population densities that were comparable to those in continuous corn plots. In the case of *Belonolaimus* sp., however, population increase was delayed in previously fallowed soil (Figs. 1, 2), resulting in more vigorous seedling corn growth.

Numerous weed species have been described as being excellent hosts for species of *Belonolaimus* (4,11), and this appears to be true for Kansas populations as well. Feeding damage was observed on roots of crabgrass (*Digitaria sanguinalis* (L.) Scop.) and puncturevine (*Tribulus terrestris* L.), and isolated patches of these plants may have been responsible for the survival of *Belonolaimus* sp. in fallowed plots. As with other *Belonolaimus* spp., comprehensive weed control is essential in any rotation designed to manage these nematodes (11).

Although wheat proved to be a suitable host for *Belonolaimus* sp. under greenhouse conditions, obvious damage to field-grown wheat has not yet been attributed to this nematode in Kansas. A similar observation was made for oats in South Carolina (4). It appears that environmental conditions may be unfavorable for much activity by this nematode during winter grain production, but this needs to be investigated further.

Previous research has indicated that the vertical distribution of populations of *Belonolaimus* spp. in the soil profile can shift as the season progresses (8,15). Results from this study confirm that a significant and relevant percentage of a field population of *Belonolaimus* sp. (but possibly not *P. scribneri*) can occur below standard sampling depths (e.g., 15–20 cm), particularly early and late in the growing season. Movement of *Belonolaimus* sp. populations from lower to upper soil depths appears to be a contributing factor in rapid increases in nematode densities around seedling crops immediately after planting. This increases sampling error and could lead to an underestimation of crop loss. It may also explain why some crop thresholds are near the detection limits for this nematode. For these reasons, an adjustment for "depth efficiency" of sampling procedures has been suggested (8).

This study has provided evidence that crop rotation is a viable option for the management of *Belonolaimus* sp. and *P. scribneri* in irrigated sandy soils in Kansas. A rotation sequence that incorporates 3–4 years of continuous alfalfa production would be most effective for managing these nematodes, because an extended duration under a nonhost crop should result in maximum suppression of targeted nematode populations. Caution is imperative, however, because prolonged production periods of alfalfa can favor the buildup of new pest species, such as *Ditylenchus dipsaci* (Kuhn) Filipjev.

Literature Cited

1. Christie, J. R., and V. G. Perry. 1951. Removing nematodes from soil. Proceedings of the Helminthological Society of Washington 18:106–108.

2. Doggett, H. 1988. Sorghum. Essex, England: Longman Scientific and Technical.

3. Georgi, L., J. M. Ferris, and V. R. Ferris. 1983. Population development of *Pratylenchus hexincisus* in eight corn inbreds. Journal of Nematology 15:243–252.

4. Holdeman, Q. L., and T. W. Graham. 1953. The effect of different plant species on the population trends of the sting nematode. Plant Disease Reporter 37:497–500.

5. Jardine, D. J., and T. C. Todd. 1990. The sting nematode. Cooperative Extension Bulletin L-817, Kansas State University, Manhattan.

6. McSorley, R., and D. W. Dickson. 1989. Effects and dynamics of a nematode community on maize. Journal of Nematology 21:462–471.

7. McSorley, R., and D. W. Dickson. 1989. Effects and dynamics of a nematode community on soybean. Journal of Nematology 21:490–499.

8. McSorley, R., and D. W. Dickson. 1990. Vertical distribution of plant-parasitic nematodes in sandy soil under soybean. Journal of Nematology 22:90–96.

9. Milliken, G. A., and D. E. Johnson. 1984. Analysis of messy data, vol. 1: Designed experiments. New York: Van Nostrand Reinhold Company.

10. Perry, V. G., and H. L. Rhoades. 1982. The genus *Belonolaimus*. Pp. 144–149 *in* R. D. Riggs, ed. Nematology in the southern region of the United States. Southern Cooperative Series Bulletin 276, Arkansas Agricultural Experiment Station, Fayetteville.

11. Robbins, R. T., and K. R. Barker. 1973. Comparisons of host range and production among populations of *Belonolaimus longicaudatus* from North Carolina and Georgia. Plant Disease Reporter 57:750–754.

12. SAS Institute. 1985. SAS user's guide: Statistics, version 5. Cary, NC: SAS Institute.

13. Smolik, J. D., and P. D. Evenson. 1987. Relationship of yields and *Pratylenchus* spp. population densities in dryland and irrigated corn. Supplement to the Journal of Nematology 19:71–73.

14. Sydenham, G. M., and R. B. Malek. 1989. Comparative host suitability of selected crop species for *Pratylenchus hexincisus* and *P. scribneri*. Journal of Nematology 21:590 (Abstr.).

15. Todd, T. C. 1989. Population dynamics and damage potential of *Belonolaimus* sp. on corn. Supplement to the Journal of Nematology 21:697–702.

16. Todd, T. C., and L. P. Paris. 1986. Evaluation of nematicides for control of lesion nematodes on corn. Fungicide and Nematicide Tests 41:75.