

Population Dynamics and Damage Potential of *Belonolaimus* sp. on Corn¹

T. C. TODD²

Abstract: The population dynamics and damage potential of an undescribed species of *Belonolaimus* were investigated for 2 years in a naturally infested commercial corn field in southwestern Kansas and for a third year in a field microplot study. Population trends and vertical distribution of nematode life-stages were monitored and relationships between corn yields and initial or midseason nematode population densities were described using regression analyses. Nematode populations in field plots and in the top 30 cm of microplots increased following seedling emergence, then declined steadily. Numbers of adult nematodes remained relatively stable in all studies, but shifts were observed in the vertical distribution of females in microplots. Females and juveniles in microplots were concentrated in the upper 30 cm of soil 3 weeks after planting but were below normal sample depths by mid-July. Corn yields decreased linearly with increasing initial and midseason nematode population densities.

Key words: *Belonolaimus* sp., corn, crop loss, damage potential, population dynamics, sting nematode, vertical distribution, *Zea mays*.

An undescribed species of *Belonolaimus* is frequently associated with severely stunted corn (*Zea mays* L.) and, more recently, soybean (*Glycine max* (L.) Merr.) and sorghum (*Sorghum bicolor* (L.) Moench) in southwestern and southcentral Kansas. Morphometrics of the nematode are nearest those described for *Belonolaimus nortoni* Rau (10), but total length, stylet length, and tail length are greater for the Kansas populations. These and other characteristics conform to the description of a Nebraska population of *Belonolaimus* sp. (5), indicating a regional distribution for the species.

The nematode appears to be endemic to the deep sandy soils of the Arkansas River flood plain, but, as reported for *Belonolaimus longicaudatus* Rau (1,8,11), it attains high population levels only in irrigated soils exceeding 80% sand content. Crops in infested fields exhibit patterns of stunting and root injury typically associated with this genus (8).

Crop production is severely limited by *Belonolaimus* sp. in localized areas of Kansas (Todd, unpubl.). Populations of the nema-

tode are frequently erratic at standard sampling depths, however, making detection and damage prediction difficult. Development of long-term management strategies requires more information on the population dynamics and life history of this nematode. The objectives of this research were to describe spatial and temporal fluctuations in populations of *Belonolaimus* sp. under field conditions, to monitor reproduction and changes in the age structure of populations, and to develop regression models for estimating threshold levels and predicting yield losses for corn in *Belonolaimus*-infested fields in Kansas.

MATERIALS AND METHODS

Experiments were conducted in naturally infested Tivoli fine sand (93% sand, 0-2% silt, 5-7% clay; pH 6.2-6.5, < 1% organic matter) in a commercial corn field in Finney County, Kansas, in 1984-85 and in microplots at the Rocky Ford Experimental Field near Manhattan in 1986-87.

Field experiments: Temporal changes in the density and age structure of a field population of *Belonolaimus* sp. were monitored in the untreated control plots (n = 32) of a 1984 nematicide study on corn (13). Composite soil samples were collected from the top 20 cm of soil at planting on 23 May and at ca. 6-week intervals through harvest on 25 September. Nematodes were ex-

Received for publication 24 February 1989.

¹ Contribution no. 89-331-J from the Kansas Agricultural Experiment Station, Manhattan, KS 66506.

² Department of Plant Pathology, Throckmorton Hall, Kansas State University, Manhattan, KS 66506.

The author thanks Dr. R. T. Robbins for his advice on species identification.

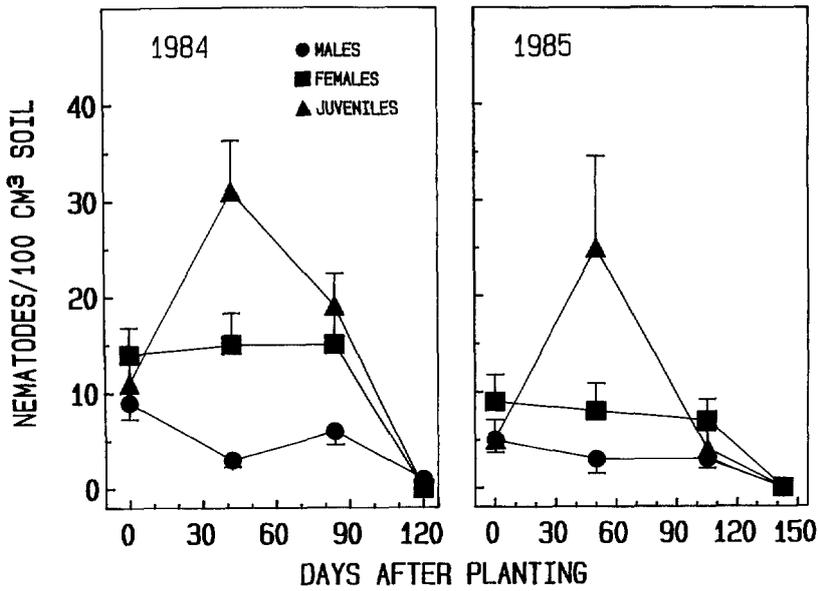


FIG. 1. Changes in populations of *Belonolaimus* sp. life-stages in field plots in 1984-85. Values are means \pm standard error.

tracted from 100-cm³ subsamples of soil using a modified Christie-Perry technique (2) and numbers of males, females, and juveniles were recorded. The relationship of numbers of *Belonolaimus* sp. to damage was assessed with linear regression analysis of data from the nematicide test. The site was treated with nematicides and replanted on 15 May 1985. Life-stages of the nematode were monitored in untreated control plots and damage potential was assessed as described for 1984.

Microplot experiment: *Belonolaimus*-infested Tivoli fine sand was collected on 24 May 1986, and one-half of the total soil volume was fumigated with methyl bromide and aerated for 72 hours. Buried PVC cylinders (25 cm d \times 75 cm deep) were filled with *Belonolaimus*-infested sand uniformly mixed with methyl bromide-fumigated sand at ratios of 0:1, 1:3, 1:1, 3:1, and 1:0. Measured initial population densities (Pi) were 0, 2, 6, 6, and 18 nematodes/100 cm³ soil. Each microplot was seeded with four Pioneer 3183 corn seeds on 29 May 1986 and thinned to one seedling upon emergence.

Vertical distribution and age structure of nematode populations in microplots

were monitored at 3-week intervals during the growing season. On each sampling date, 2-cm-d soil cores were collected at depths of 0-15, 15-30, 30-45, 45-60, and 60-75 cm and processed as described for the field samples. Nematodes were categorized as second-stage juveniles (J2), third-stage or fourth-stage juveniles (J3-J4), males, or females. Post-harvest survival of *Belonolaimus* sp. was determined from soil cores collected on 11 December 1986 and 18 May 1987 using the same procedures. Plant heights were recorded on each nematode sampling date and corn yields were determined from ears collected on 24 September.

Treatments (Pi) were arranged in a randomized complete block design with four replications. The experiment was subjected to analysis as a split-split plot with Pi as whole plots, sampling date as subplots, and depth as sub-subplots. Sampling date and depth effects were treated as repeated measures, the Huynh-Feldt condition of independent errors was tested, and degrees of freedom were adjusted as necessary to obtain a suitable analysis (7,12). Nematode population data were log-transformed ($\log_{10} [x + 1]$) before subjecting them to analysis of variance. Corn yields were re-

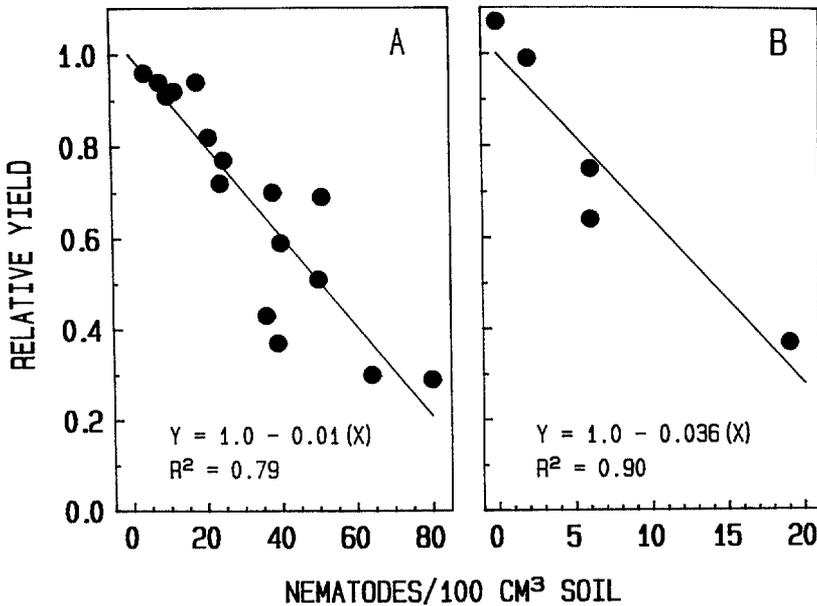


FIG. 2. Regressions of corn yields against soil densities of *Belonolaimus* sp. A) Midseason nematode densities in 1984 nematicide test. B) Initial population densities in microplots. Data points are means of four replications.

lated to nematode Pi using regression methods.

RESULTS

Field experiments: Population dynamics of *Belonolaimus* sp. were similar for both 1984 and 1985. Population densities of males and females fluctuated little through mid-August, then decreased to barely detectable levels by mid-September (Fig. 1). Juveniles (predominately J3 and J4) exhibited a single peak 6 weeks after planting, when they comprised 63–69% of the total population, then steadily declined through harvest. Males composed the smallest proportion of the population, ranging from 26% at planting in both years to an average of 7% 6 weeks after planting (38% and 22% of the adult population at planting and 6 weeks after planting, respectively).

The relationship between 1984 corn yields and treatment means of *Belonolaimus* sp. populations 6 weeks after planting was representative of both years and was best described by the linear regression model depicted in Figure 2A. A 1% yield loss occurred for each nematode present in 100 cm³ soil at midseason.

Microplot experiment: Temporal changes

in the depth stratification of nematode populations in microplots were specific for each life-stage (Table 1, Fig. 3). Patterns of vertical distribution were generally independent of Pi, however, and are therefore described as averages across initial nematode levels (Fig. 3). Numbers of males remained relatively stable, exhibiting no significant trends, although population densities did temporarily decline following planting (Table 1, Fig. 3A). The vertical distribution, but not total numbers, of fe-

TABLE 1. Analysis of variance for initial population density, depth, and time effects on *Belonolaimus* sp. life-stages in microplots.

Source of variation	Mean squares			
	Males	Females	J3-J4	J2
Block	0.42	0.05	0.12	0.14
Initial population (Pi)	0.69	0.45	0.87*	0.61
Error A	0.31	0.15	0.18	0.18
Date	0.52	0.01	0.03	0.58*
Pi × date	0.08	0.23	0.12	0.23
Error B	0.20	0.12	0.31	0.11
Depth	0.28	0.54*	0.02	0.50*
Pi × depth	0.14	0.20	0.20	0.17
Date × depth	0.06	0.88*	0.40*	0.30*
Pi × date × depth	0.10	0.19	0.27*	0.15
Error C	0.13	0.16	0.17	0.14

* P ≤ 0.05.

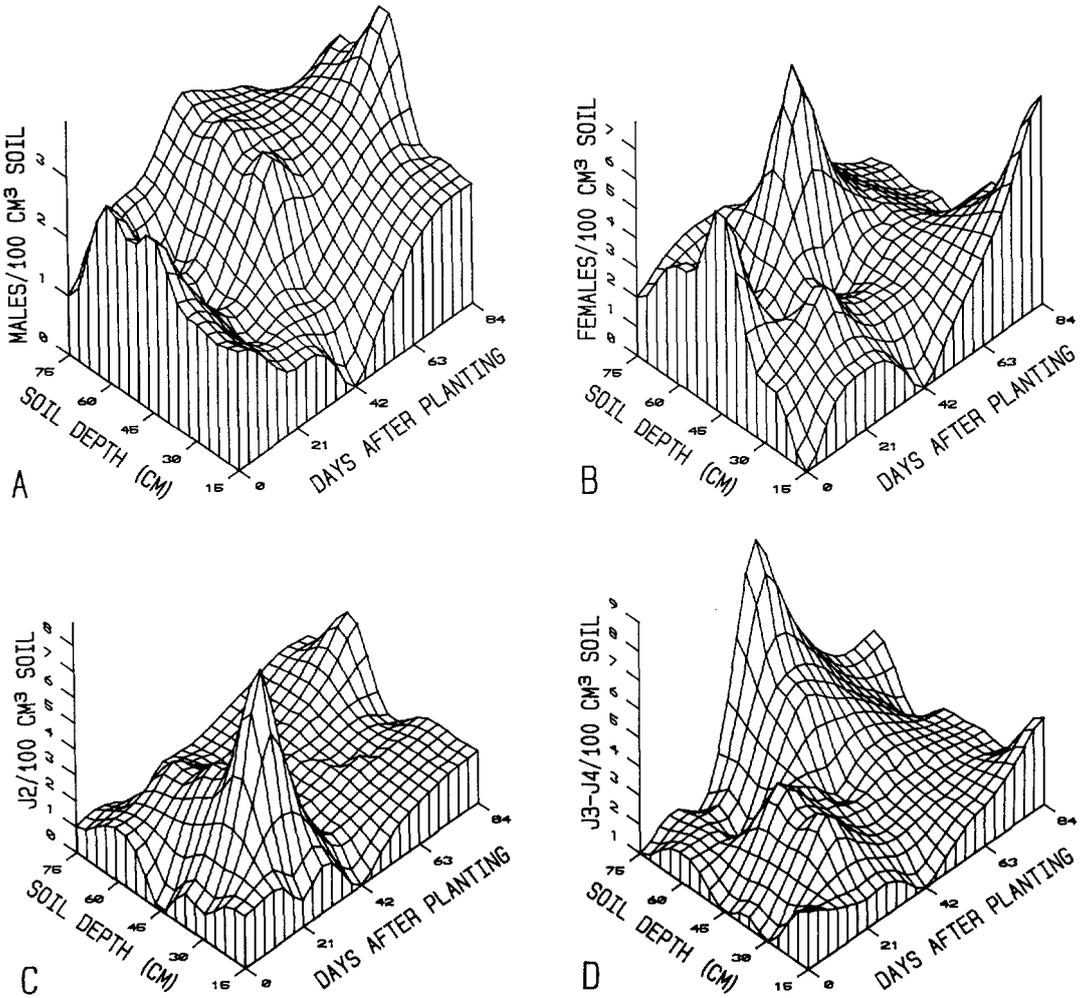


FIG. 3. Vertical and temporal distribution of *Belonolaimus* sp. in microplots in 1986. A) Males. B) Females. C) Second-stage juveniles (J2). D) Third-stage and fourth-stage juveniles (J3-J4).

males varied ($P \leq 0.05$) throughout the season (Table 1, Fig. 3B). The majority of the female population (60–70%) was concentrated at depths of 0–30 cm, 45–60 cm, and 0–30 cm at 21, 42, and 84 days, respectively. A significant date \times depth interaction was also observed for the juvenile stages (Table 1). An increase in numbers of J2 occurred at the 15–30-cm depth by day 21, followed by a decline and then another increase throughout the soil profile on the last sampling date (Fig. 3C). Three weeks after the first increase in J2 populations, a peak was observed in J3–J4 populations (Fig. 3D). These later stage juveniles exhibited trends in time and depth

similar to those observed for the females. An interaction ($P \leq 0.05$) between Pi, date, and depth for J3–J4 densities appeared to be restricted to the top two depths on the last sampling date and does not influence the interpretation of population trends.

The post-harvest dynamics of *Belonolaimus* sp. populations were influenced by depth in the soil profile (Fig. 4). Nematodes decreased at a constant rate across all depths with the exception of the top 15 cm, where the rate of population decline was greater. During the 3 months following harvest, nematode densities decreased 67% at depths below 15 cm and 100% above 15 cm. Nematodes were at barely detect-

able levels by May 1987. Survival rates were further influenced by Pi, with 12% of highest and 50% of lowest August populations recoverable on 11 December.

Corn yields in microplots decreased linearly with increasing nematode Pi levels (Fig. 2B). Initial population densities of females at the 30–45-cm depth provided the best correlations with yield ($r = -0.52, P = 0.02$) and plant height throughout the season ($r = -0.72$ to $-0.86, P < 0.01$).

DISCUSSION

Early-season changes in soil densities of *Belonolaimus* sp. in the top 30 cm of microplots followed trends similar to those observed in field plots. Populations increased primarily because of egg production in the root zone as measured by an increase in numbers of J2 in microplots 21 days after planting and J3–J4 in field plots 40–50 days after planting (Figs. 1, 3). Subsequent reductions in populations in the upper soil depths in microplots appeared to result from downward migrations of females and late-stage juveniles. This observation suggests that the disappearance of the nematode from late-season field samples might be explained by similar behavior. The aggregation of females and J3–J4 in the top 15–30 cm of the soil profile following seedling emergence and later at depths exceeding 45 cm probably is related to the nematode’s preferential feeding at root tips (8), although moisture fluctuations at the soil surface may be responsible for downward migrations. This pattern of vertical distribution was observed for other nematodes that inhabit soils of high sand content (6). The resurgence of nematode populations in the top 15 cm of microplots just before harvest probably is an artifact of the microplot environment, with nematodes responding to unknown gradients in the soil column. It has been suggested that, in the absence of a chemical stimulus, nematodes migrate to particular soil depths in response to thermal gradients (3). Studies have also shown that upward migration can be stimulated by soil moisture gradients (9). Such responses may explain the late-

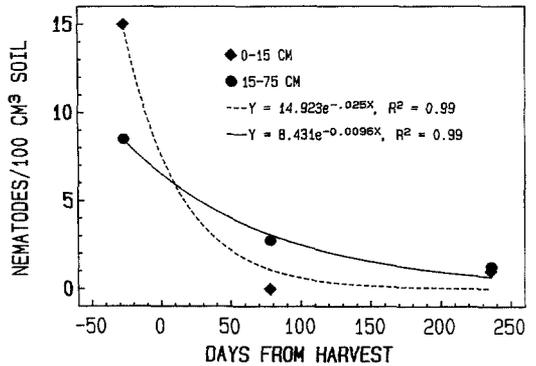


FIG. 4. Post-harvest decline of microplot populations of *Belonolaimus* sp. at soil depths above and below 15 cm. Y = predicted nematode density; X = number of days after pre-harvest sampling date.

season migration observed in microplots as well as the moderate levels of *Belonolaimus* sp. recovered from field samples in May 1985 when populations were barely detectable in samples collected at the same site the previous September.

The adaptive significance of the location of nematode populations in the soil profile following harvest is indicated by the comparison of overwinter survival rates in Figure 4, with populations in the top 15 cm decreasing at a much higher rate than those at lower depths. Differences in survival rates probably reflect soil temperature and moisture effects, although the greatest population reductions occurred before extreme temperature conditions.

Nematode densities in microplots with different levels of Pi tended to become more similar with time and were not different following harvest. Rates of increase and survival decreased with increasing Pi, indicating that density-dependent factors operate in populations of *Belonolaimus* sp. as observed for other nematodes (4). Since the amount of damage per nematode is high, populations apparently are influenced by relatively small differences in density.

Life-stage data collected from these experiments conform to prior estimates that the life cycle in *Belonolaimus* spp. is completed in approximately 1 month (8). Egg production appears to occur predominately in the first few weeks after seedling

emergence, with peaks in J2 and J3-J4 populations appearing at 3 and 6 weeks after planting, respectively. Adult populations remain relatively stable, with development of juvenile stages apparently offsetting deaths. More precise measurements of the development and survival of this nematode are necessary before long-term population trends can be predicted.

Field and microplot data indicate that yield losses due to this species of *Belonolaimus* are adequately described by linear regressions. The threshold level for yield reductions in corn appears to be at or below detectable levels of the nematode. Such a high potential for damage, confounded by the migratory behavior of the nematode, emphasizes the need for using sampling strategies that increase the precision and accuracy of population estimates and that consider the dispersal of nematode populations vertically, as well as horizontally.

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