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Damage Function and Economic Threshold for *Belonolaimus longicaudatus* on Potato[1]

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Abstract: *Belonolaimus longicaudatus* has long been recognized as a pathogen of potato (*Solanum tuberosum*). However, a damage function relating expected yield of potato to population densities of *B. longicaudatus* at planting has not been derived, and the economic threshold for nematicide application is unknown. The objectives of this study were to derive the damage function of *B. longicaudatus* on potato and to calculate the economic threshold population density. The damage function data for *B. longicaudatus* on potato were obtained from an ongoing field study to evaluate cropping systems and nematode management practices. Soil samples were collected from experimental field plots, and nematodes were extracted from a 130-cm^3 subsample with a centrifugal-flotation method. A damage function was derived by linear regression of potato yield on nematode population density at planting. Based on this derived damage function and published potato prices, the economic threshold for nematicide application was calculated at 2 to 3 *B. longicaudatus*/130 cm^3 of soil, which was near the detection threshold based on methodology used in this study.

Key words: *Belonolaimus longicaudatus,* damage function, economic threshold, nematode, plant disease loss, potato, *Solanum tuberosum,* sting nematode.

Belonolaimus longicaudatus Rau (sting nematode) is a destructive pathogen of many economically important plants (Perry and Rhoades, 1982; Smart and Nguyen, 1991). Sting nematode is found primarily in the sandy coastal plains of the southeastern United States and is limited in soils with <80% sand content (Robbins and Barker, 1974). Currently, northeastern Florida has the only important potato (*Solanum tuberosum* L.) production area where sting nematode is commonly found (Brodie, 1998). Sting nematode is present in most of the potato fields in this region (Nguyen and Smart, 1975; Weingartner et al., 1977).

All commercial potato fields in northeastern Florida are treated with nematicides each year for management of *B. longicaudatus, Meloidogyne incognita, Trichodorus* spp., and *Paratrichodorus minor;* the latter two nematodes transmit tobacco rattle virus (Weingartner et al., 1993; Weingartner and Shumaker, 1983). The use of nematicides has been associated with significant yield increases in the region, attributed primarily to management of *B. longicaudatus* (Weingartner et al., 1993; Weingartner and Shumaker, 1983).

In greenhouse tests, potato was an excellent host of *B. longicaudatus* (Robbins and Barker, 1973), which also was associated with yield losses of potato in the field (Weingartner et al., 1977, 1978). However, the relationship between *B. longicaudatus* and potato has not been quantified as a damage function. Knowledge of the economic threshold population density, the point at which the expected decline in crop value is equal to management cost (Ferris, 1978), would be useful in order to avoid unnecessary nematicide applications. Our objective was to derive the damage function for *B. longicaudatus* and use it to calculate the economic threshold population density.

Materials and Methods

A 2-year field study was carried out during 1997 and 1998 for quantifying yield losses in 'Atlantic' potato due to root damage caused by *B. longicaudatus.* This study was part of a larger cropping system study conducted at the University of Florida Agricultural Research and Education Center's Yelvington

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Farm near Hastings, Florida (Crow, 1999). The site selected was naturally infested with *B. longicaudatus, Mesocriconema* sp., *Dolichodorus heterocephalus, Hemicycliophora* sp., *Meloidogyne incognita* race 1, *Paratrichodorus minor, Pratylenchus brachyurus, P. zeae,* and *Tylenchorhynchus* sp. The soil was an Ellzey fine sand (sandy, silicaceous, hyperthermic Arenic Ochraqualf) composed of 95% sand, 2% silt, 3% clay; <1% organic matter; pH 6.5 to 7.0.

Initial nematode population densities (Pi) were modified by prior cropping system and soil fumigation to obtain a wide range of nematode population densities. A split-plot design was used with cropping system as the whole plot and nematicide treatment as the subplot. Cropping treatments were: (i) winter-spring 'Atlantic' potato followed by a cover crop of sorghum-sudangrass hybrid (*Sorghum bicolor* (L.) Moench × *S. arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.), both hosts for *B. longicaudatus* (McSorley and Dickson, 1995; Robbins and Barker, 1973); (ii) winter-spring potato in 1-year rotation with summer cotton (*Gossypium hirsutum* L.), a host for *B. longicaudatus* (Graham and Holdeman, 1953); (iii) winter-spring potato double-cropped with summer cotton; and (iv) winter-spring potato followed by a summer cover crop of velvetbean (*Mucuna pruriens* (Wallich ex Wight) Baker ex Burck, syn. *M. deeringiana*), a non-host for *B. longicaudatus* (McSorley and Dickson, 1995). Nematicide treatments were an untreated control and a treatment in which plots were fumigated with 1,3-dichloropropene (1,3-D) at the rate of 56 liters/ha (570 ml/100-m row) with a single chisel per row. Each treatment had five replications.

The experiment was carried out on ridged rows with 102-cm spacing between rows, and the plot area was watered by seepage irrigation. Field plots were 4 rows wide and 9 m long. Two clean fallow rows were maintained between adjacent plots, and 3 m of clean fallow were maintained between plots in the same rows. All nematode and yield data were collected from the inner two rows of each plot.

Potato seed pieces were planted 10 February 1997 and 27 February 1998, and harvest dates were 5 May 1997 and 8 June 1998, respectively. Potato tubers were harvested with a single-row mechanical harvester. Following harvest, tubers were graded by size with a mechanical grader and weighed. Only tubers ≥3.81 cm-diam. were included in the analysis.

Soil samples were collected 1 day before planting. Twelve 2.5-cm-diam. cores were taken 20 cm deep from each plot, and composited. Nematodes were extracted from a 130-cm^3 subsample by centrifugal-flotation (Jenkins, 1964) modified by doubling the sugar concentration. Following extraction, nematodes were counted on an inverted light microscope at ×32 magnification.

Multiple-regression analysis was used to compare the relative degrees of association of the different plant-parasitic nematodes present with potato yields. Potato yields were regressed on Pi of all genera of plant-parasitic nematodes with stepwise multiple regression (Ott, 1993). Multiple-regression analysis was performed with SAS software (SAS Institute, Cary, NC). Nematodes contributing the most to the R^2 of the stepwise regression model were considered to have the greatest effect on yield (McSorley and Waddill, 1982). Linear regression of yield on Pi (Ott, 1993) was used to generate damage functions for *B. longicaudatus* on potato. Linear regression was performed with Excel software (Microsoft, Redmond, WA). Damage functions derived for each year were tested for heterogeneity of slope to detect variability between the 2 years.

Following derivation of damage functions, published economic data were used to establish economic thresholds for nematicide application. Published market values (Anonymous, 1999) for potato during the harvest months of 1997 and 1998 were multiplied by the average slope of the damage function derived from the data for the 2 years. This value was used as an estimate of the dollar value of yield reduction associated with each *B. longicaudatus* detected in a soil sample. The cost of nematicide treatment was then divided by the estimated loss per nematode to calculate the economic threshold density.

Results

As determined by stepwise multiple-regression analysis, *B. longicaudatus* was the only plant-parasitic nematode with a significant relationship to potato yield in both years. The only other nematode that contributed significantly to the model in either year was *D. heterocephalus* in 1997 ($P = 0.03$, $r^2 = 0.05$). The relationship between yield (Y) and Pi of *B. longicaudatus* per 130 cm^3 of soil (x) was described by a linear model for 1997 and for 1998 (Fig. 1). These slopes were not heterogeneous ($P = 0.973$), but the Y intercepts were different. Based on the average slope of the 2 years ($-0.199x$), each nematode detected in a soil sample was associated with a 199-kg/ha reduction in potato tuber yield.

Regional commercial potato prices during the study period ranged from $0.23/kg to $0.45/kg (Anonymous, 1999) (Table 1). When the slope of the damage function was multiplied by potato price, the dollar loss per nematode detected ranged from $46 to $89/hectare. The cost of nematicide application was $159/ha for aldicarb at 3.36 kg a.i./ha, and $149/ha for 1,3-D at 56 liters/ha 1,3-D (Smith and Taylor, 1999). These values were divided by the dollar losses per nematode to determine the economic threshold for *B. longicaudatus*. Economic threshold densities were 2 to 3 *B. longicaudatus*/130 cm^3 of soil (Table 1).

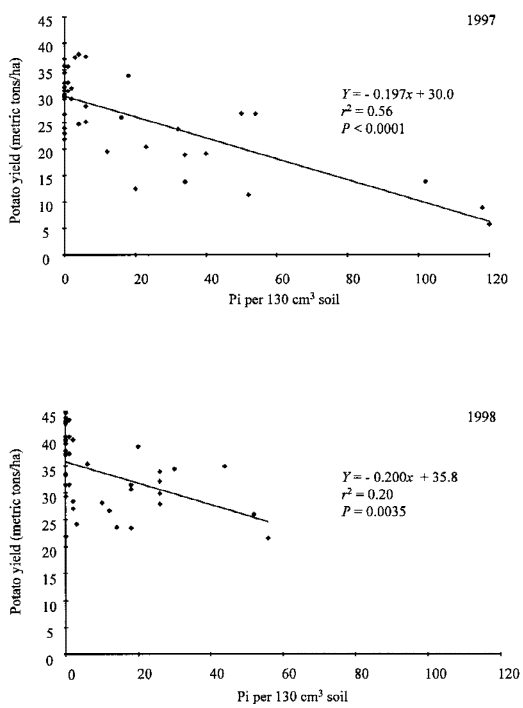

Fig. 1. Damage functions for *Belonolaimus longicaudatus* on potato in 1997 and 1998. The damage functions are derived by the linear regression of potato tuber yield (metric tons/hectare) on initial population density (Pi) of *B. longicaudatus*.

Discussion

The typical model for yield reduction caused by plant-parasitic nematodes has a downward sloping sigmoidal shape (Seinhorst, 1965). According to the Seinhorst model, there is a tolerance population density, or tolerance limit. At Pi densities below the tolerance limit, yield is not reduced (Seinhorst, 1965). Seinhorst (1965) also introduced the concept of minimum yield. The minimum yield is that at which no further reductions occur regardless of increases in nematode Pi density. Tolerance limits for a pathogenic nematode such as *B. longicaudatus* may be below or near the detection level. In addition, high Pi may result in such severe yield losses that minimum yield is near zero. Under these circumstances, only the portion of the Seinhorst (1965) model with Pi densities between the detection limit and that capable of causing zero yield would be of practical consideration. This portion of the Seinhorst (1965) model is roughly linear in shape, and the effects of individual nematodes are largely additive. A linear model relating plant damage to Pi density may be as valid in these circumstances as the typical Seinhorst (1965) model and has been used to describe damage functions for *Belonolaimus* spp. on other crops (Crow et al., 2000; McSorley and Dickson, 1989; Todd, 1989).

From these data, which were generated by intensive sampling of small plots, it is determined that the economic threshold for *B. longicaudatus* on potato is near the detection

TABLE 1. Economic thresholds for *Belonolaimus longicaudatus* on potato based on current production costs and crop values in U.S. dollars.

Date	Potato price ($/kg)	Monetary loss ($/nematode)	Threshold for aldicarb (Nematodes/130 cm^3 of soil)	Threshold for 1,3-D (Nematodes/130 cm^3 of soil)
April 1997	0.29[a]	57[b]	3[c]	3
May 1997	0.24	48	3	3
June 1997	0.25	50	3	3
April 1998	0.45	89	2	2
May 1998	0.25	50	3	3
June 1998	0.23	46	3	3

[a] Average potato price received by northeastern Florida producers in the current month.
[b] Potato price was multiplied by slope of the linear damage function (−199 kg/ha yield reduction/nematode) to obtain the monetary loss per hectare associated with each nematode detected in a 130-cm^3 soil sample.
[c] Cost of nematicide application per hectare ($159/ha for aldicarb, $149/ha for 1,3-dichloropropene) was divided by the monetary loss per nematode to derive the economic threshold for management of *B. longticaudatus* with each nematicide.

threshold. Sampling error in small plots is less than in large commercial fields because, as the size of the sampled area increases, the sampling error also increases (McSorley and Parrado, 1982). Therefore, the preciseness of the economic threshold for a typical grower's field may be adversely affected because of the large size and sampling error. Any detectible level of *B. longicaudatus* in commercial fields is likely to exceed the economic threshold for potato, and treatment may be recommended at the detection level.

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