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Population Dynamics of *Belonolaimus longicaudatus* in a Cotton Production System[1]

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Abstract: *Belonolaimus longicaudatus* is a recognized pathogen of cotton (*Gossypium hirsutum*), but insufficient information is available on the population dynamics and economic thresholds of *B. longicaudatus* in cotton production. In this study, data collected from a field in Florida were used to develop models predicting population increases of *B. longicaudatus* on cotton and population declines under clean fallow. Population densities of *B. longicaudatus* increased on cotton, reaching a carrying capacity of 139 nematodes/130 cm^3 of soil, but decreased exponentially during periods of bare fallow. The model indicated that population densities should decrease each year of monocropped cotton, if an alternate host is not present between sequential cotton crops. Economic thresholds derived from published damage functions and current prices for cotton and nematicides varied from 2 to 5 *B. longicaudatus*/130 cm^3 of soil, depending on the nematicide used.

Key words: *Belonolaimus longicaudatus,* cotton, economic threshold, fallow, *Gossypium hirsutum,* modeling, nematode, population decline, population dynamics, population increase, sting nematode.

Belonolaimus longicaudatus Rau (sting nematode) is a virulent pathogen of cotton (*Gossypium hirsutum* L.) (Graham and Holdeman, 1953; Crow et al., 2000a) limited primarily to soils composed of ≥80% sand and <10% organic matter (Robbins and Barker, 1974). Cotton is not typically grown in such sandy soils, however, and surveys of cotton fields in the southeastern United States have rarely detected *B. longicaudatus* associated with cotton (Baird et al., 1996; Kinloch and Sprenkel, 1994; Martin et al., 1994). During the 1990s, high cotton prices led to expansion of cotton production into areas such as northeastern Florida with soils that favor *B. longicaudatus*.

Nematode population dynamics models predict whether nematode problems will stabilize, increase, or decrease over time in a given production system (Ferris et al., 1994). The economic threshold is defined as the value at which the expected increase in return per hectare is equal to the variable costs (e. g., nematicide and application costs) of management (Ferris, 1978). Nematode population dynamics models, along with economic thresholds, can give growers tools with which to evaluate nematode management strategies not only for the current crop but for their cropping system over time (Barker and Noe, 1987; Ferris et al., 1994). Neither population dynamics models nor economic thresholds for *B. longicaudatus* in cotton production have been previously reported.

Population dynamics of *B. longicaudatus* on cotton may be influenced by the cotton cultivar and by variations among nematode isolates. 'Coker 100WR' cotton was a good host for *B. longicaudatus* from South Carolina (Holdeman and Graham, 1953), but 'Stoneville 7A' cotton was a poor host for populations from North Carolina and Georgia (Robbins and Barker, 1973). *Belonolaimus longicaudatus* population densities were <30 nematodes/100 cm^3 of soil following 'Georgia King' cotton in Tifton, Georgia (Johnson et al., 1998). In another test at the same location, population densities were >150 *B. longicaudatus*/100 cm^3 of soil following 'Coker 413–67' cotton (Johnson, 1970).

The objectives of this study were to develop population dynamics models and economic thresholds for *B. longicaudatus* on cotton in northeastern Florida based on data from a cropping system study in St. Johns

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County, Florida, and on published economic data.

Materials and Methods

A 3-year field experiment was conducted from January 1996 to January 1999 to study the population dynamics and plant damage of *B. longicaudatus* on potato and cotton (Crow, 1999). Only portions of the data collected from this experiment are reported herein. The field was on the Yelvington Farm at the University of Florida Agricultural Research and Education Center near Hastings, Florida, and 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; 95% sand, 2% silt, 3% clay; <1% organic matter; pH 6.5 to 7.0).

Population increases: Twenty-five plots were planted (Table 1) to 'DPL 5415' cotton in 1997 and 1998. There was considerable variation in population densities of *B. longicaudatus* at planting among these plots due to the previous crop, length of fallow between crops, and whether or not soil was fumigated with 1–3 dichloropropene (1,3-D) before planting. Ten of the plots followed cotton and 7 months of fallow; of these, five were fumigated with 1,3-D and five were untreated. Ten plots followed sorghum-sundangrass (*Sorghum bicolor* (L.) Moench × *S. arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.) and 8 months of fallow; of these, five were fumigated with 1,3-D and five were untreated. Five plots followed potato (*Solanum tuberosum* L.) and <1 month of fallow; these were untreated.

Table 1. Treatments used to adjust population densities of *Belonolaimus longicaudatus* at planting for the population increase experiment.

Treatment	Previous crop	Months of fallow	Nematicide
1	Cotton	7	Untreated
2	Cotton	7	1,3-Dichloropropene
3	Sorghum-sudangrass	8	Untreated
4	Sorghum-sudangrass	8	1,3-Dichloropropene
5	Potato	<1	Untreated

In both years, soil samples were collected at cotton planting and harvest to determine the population density of *B. longicaudatus.* Twelve 2.5-cm-diam, cores were collected from the two center rows of each four-row plot and composited. Nematodes were extracted from a 130-cm^3 subsample with a centrifugal-flotation method (Jenkins, 1964), modified by doubling the sugar concentration. Following extraction, nematodes were counted with an inverted light microscope (×32).

Models were developed quantitatively relating initial population density of *B. longiaudatus* at planting (Pi) with final population density at harvest (Pf) using both nontransformed and ln $(x + 1)$ transformed data. Data from both years were combined. The relationships of Pf to Pi were subjected to regression analysis (Ott, 1993) in which Pf densities were regressed on Pi densities, and ln (Pf + 1) transformed densities were regressed on ln (Pi + 1) transformed densities. Nontransformed population densities were regressed using a quadratic model, and ln transformed densities were regressed using a linear model. Regression analysis was performed using the Excel software program (Microsoft Corporation, Redmond, WA). The carrying capacity for *B. longicaudatus* on cotton was defined as the maximum expected Pf as derived from the quadratic equation. Cotton was considered a good host if the linear regression line for the ln transformed data was above the maintenance line, where ln (Pi + 1) = ln (Pf + 1).

Population declines: A population decline model for *B. longicaudatus* under clean fallow was derived from data collected during winters of 1996 to 1998 (Crow, 1999). Clean fallow periods of varying lengths were maintained in each of 18 cropping system treatments. Nematode population densities before fallow were used as Pi for the fallow, and nematode population densities at planting of the next season's crop were used as Pf for the fallow. Only plots with ≥50 *B. longicaudatus*/130 cm^3 of soil Pi were included. A total of 254 data points from 15 different fallow lengths were used.

The proportion of *B. longicaudatus* remaining at the end of each fallow period was determined by the (Pf + 1)/(Pi + 1) ratio. These proportions were regressed against time using a negative exponential model with Excel software to estimate decline in *B. longicaudatus* population density under clean fallow.

Results

Final population densities of *B. longicaudatus* (Y) increased on cotton for all Pi <100 nematodes/130 cm^3 soil, and declined for all Pi >130 nematodes/130 cm^3 soil (Fig. 1). The quadratic model $Y = -0.0085x^2 + 1.91x + 31.8$ ($R^2 = 0.52$, $P > 0.01$) was fitted to the untransformed data (Fig. 1). The quadratic model may be useful to account for reduction in Pf below the carrying capacity at high Pi where severe plant damage occurs (McSorley and Gallaher, 1993; Seinhorst, 1970). Assuming that the maximum value of this quadratic equation may provide a rough estimate of the carrying capacity, then from the first derivative of the quadratic regression equation, an estimated carrying capacity of 139 nematodes/130 cm^3 of soil can be obtained (Fig. 1). The linear model $Y = 0.41x + 2.82$ ($r^2 = 0.38$, $P < 0.01$) was obtained for the log transformed data (Fig. 2).

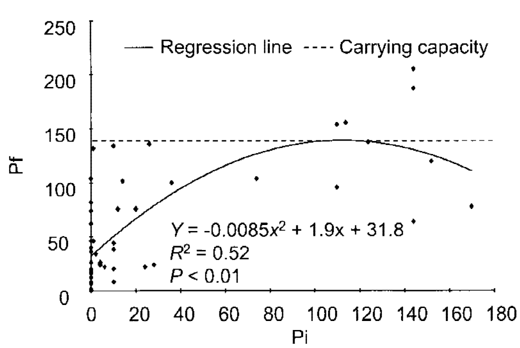

Fig. 1. Relationship of *Belonolaimus longicaudatus* final population per 130 cm^3 of soil (Pf) and the initial population per 130 cm^3 of soil (Pi) on cotton. The carrying capacity is the maximum expected Pf derived from the quadratic equation.

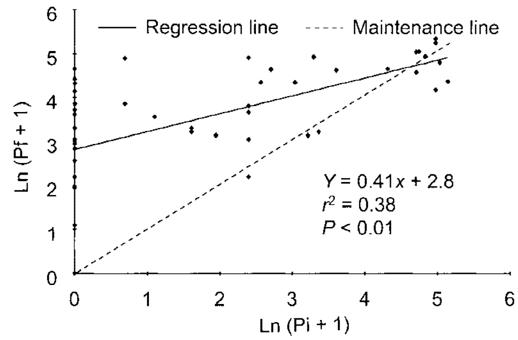

Fig. 2. Linear regression of the log of the final population density (Pf) per 130 cm^3 of soil against the log of the initial population density (Pi) per 130 cm^3 of soil for *Belonolaimus longicaudatus* on cotton. The maintenance line is where 1n (Pf + 1) = ln (Pi + 1). A regression line above the maintenance line indicates that the population is increasing.

The regression line was above the so-called maintenance line (Pf = Pi) for all Pi < 4.8 (115 nematodes/130 cm^3 soil).

The population decline data were fitted to the negative exponential regression, $Y = 1.37e^{-0.013x}$ ($r^2 = 0.52$, $P < 0.0001$) (Fig. 3). Population densities of *B. longicaudatus* were predicted to decline by 42, 68, 82, 90, and

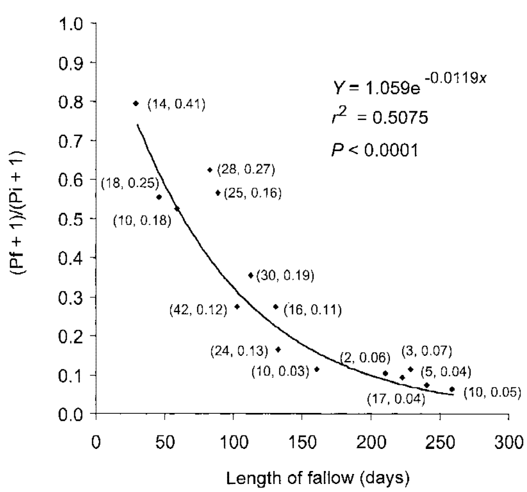

Fig. 3. Population decline model for *Belonolaimus longicaudatus* during clean fallow. The relationship is described by the negative exponential regression of the proportion of the original population remaining after fallow, (Pf + 1)/(Pi + 1), regressed on the length of fallow in days. Data points represent means. First and second numbers in parentheses represent the number of observations at each date and the standard deviation around the mean, respectively.

95% after 50, 100, 150, 200, and 250 days, respectively.

Discussion

Average cotton prices were US $1.62/kg in 1997 (Anonymous, 1999). Crow et al. (2000a) reported a decrease of 18.4 kg/ha in seed cotton yield associated with each *B. longicaudatus* per 130 cm^3 of soil detected at planting—the equivalent of US $30.84/ha at 1997 prices. A nematicide treatment of 1,3-D at the recommended rate of 56 liters/ha would cost US $157/ha in 1997, whereas an aldicarb treatment at the recommended rate of 1.68 kg a.i./ha would cost US $74 kg/ha in 1997 (Smith and Taylor, 1999). With these estimates, the economic threshold for management of *B. longicaudatus* on cotton is 5 nematodes/130 cm^3 soil for 1,3-D and 2 nematodes/130 cm^3 soil for aldicarb.

A very poor cotton stand was observed when Pi densities of *B. longicaudatus* exceeded 100 nematodes/130 cm^3 soil. When large numbers of seedlings die, and an alternative food source is lacking, nematode population densities may decline. At low Pi, cotton plant damage was not severe enough to restrict reproduction of *B. longicaudatus.* However, as Pi increased, the amount of plant damage also increased until reproduction was reduced, explaining the quadratic relationship between Pi and Pf (Seinhorst, 1970).

The population increase model predicts that when cotton is grown in soil infested with *B. longicaudatus,* the Pf for the first season will reach a maximum of 140 nematodes/130 cm^3 soil. In Florida the growing season for 'DPL 5415' cotton is 150 days, so the expected fallow interval between cotton crops in monocropping is 200 days. From the population decline model it is projected that nematode population densities would decrease by 95% during this interval. If clean fallow or a non-host cover crop were used between crops, the maximum predicted Pi for the following season (11 nematodes/130 cm^3 soil) would exceed the economic threshold for nematicide use (5 nematodes/130 cm^3 soil). Based on the population increase model, Pf at the end of the second season would be <50 nematodes/130 cm^3 soil. Thus, Pi for the third year should be $\leq$4 nematodes/130 cm^3 soil, which is near or below the economic threshold. The models therefore predict that continuous monocropping of cotton in soil infested by *B. longicaudatus* in Florida is sustainable in the absence of a host between subsequent cotton crops.

While clean fallow may be useful for nematode management, the use of cover crops between cash crops is recommended in Florida for erosion and weed control and other benefits (Chambliss et al., 2000). When winter potato, a host crop, was double-cropped with cotton, Pi of *B. longicaudatus* on cotton was always > 100 nematodes/130 cm^3 soil (Crow et al., 2000b). Rye (*Secale cereale* L.), a common winter cover crop used in cotton production in Florida, was found to maintain or increase population densities of *B. longicaudatus* (McSorley and Dickson, 1989; Robbins and Barker, 1973). Further research is needed to identify winter cover crops that are non-hosts or poor hosts for *B. longicaudatus* for use in cotton production in Florida.

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