Journal of Nematology 25(3):440–445. 1993.

Damage Functions and Population Changes of *Hoplolaimus columbus* on Cotton and Soybean[1]

J. P. Noe[2]

Abstract: Damage functions and reproductive curves were determined for *Hoplolaimus columbus* on cotton cv. Deltapine 90 and soybean cv. Gordon over 2 years in field plots in Georgia. Maximum potential yield suppressions of 18% on cotton and 48% on soybean were predicted with respect to increasing Pi. Similar functions indicated yield suppressions of 38% on cotton and 30% on soybean with respect to increasing midseason nematode densities (Pm). Maximum Pf predicted by reproductive curves were 123 and 474/100 cm^3 soil on cotton and soybean, respectively. Thresholds at which 10% yield suppression would occur were lower on soybean (Pi of 4) than on cotton (Pi of 70/100 cm^3 soil). The economic threshold for a control measure costing $72/ha was a Pi of 60/100 cm^3 soil on cotton, assuming a price for cotton lint of $1.44/kg ($0.60/lb), whereas a similar treatment would not be economically feasible on soybean at any Pi with an assumed price of $0.04/kg ($5.50/bu) soybean seed. Damage functions and reproductive curves as determined in this study offer potentially useful tools for analyzing cropping systems and providing decision tools for nematode management.
Key words: cotton, cropping system, damage function, economic threshold, *Glycine max, Gossypium hirsutum, Hoplolaimus columbus,* nematode, reproductive curve, soybean, yield.

The Columbia lance nematode, *Hoplolaimus columbus* Sher, causes losses on cotton (*Gossypium hirsutum* L.) and soybean (*Glycine max* (L.) Merr.) in the southeastern United States. Infestations of *H. columbus* may suppress yields of cotton 10–25% (14,17) and soybean 10–40% (1,4,11,12, 17,18). Population densities of *H. columbus* may increase 200–400% during a growing season under cotton or soybean (1,10,14, 17,18). Intensive management of this nematode is essential.

Management of *H. columbus* on cotton has been achieved primarily through the use of nematicides (3,14,16), whereas management on soybean has employed the use of tolerant cultivars (4,13,18,20). As nematicides continue to become less available and more expensive, increased attention is being given to sustainable management practices on both crops. Most nematode management options require field sampling and crop-loss information to determine damage thresholds for efficient, economically productive application (5,15). Nematode damage functions and reproductive curves are essential components in the formulation of these thresholds for sustainable management practices (17).

Previous research has demonstrated that damage functions and reproductive curves for *H. columbus* can be derived from data collected in small plots in naturally infested fields (17). The purpose of this study is to provide additional information on management-related host–parasite relationships for *H. columbus* on cotton and soybean in Georgia.

Materials and Methods

Data collection: Field data were collected at a site naturally infested with *H. columbus* on the Southeast Georgia Branch Experiment Station in Midville, Georgia. The soil was characterized as a Dothan sandy loam (fine-loamy, siliceous, thermic, plinthic paleudults; 69% sand, 13% silt, 18% clay, pH 5.8).

Cotton cv. Deltapine 90 was planted on 9 May 1988 and 8 May 1989. Soybean cv. Gordon was planted on 23 May 1988 and 23 May 1989. Rows were 1 m apart. Thirty-six 4-row by 6-m long plots were delimited on two experimental sites for each crop (total of 72 plots for each crop in each year), and early season nematode densities were assayed on 19 May 1988 and

Received for publication 27 November 1992.
[1] Supported in part by the Georgia Agricultural Commodity Commission for Cotton, and by state and Hatch funds allocated to the Georgia Agricultural Experiment Stations.
[2] Associate Professor, Department of Plant Pathology, University of Georgia, Athens, GA 30602-7274.
The author thanks W. T. Holladay and R. D. McNeill, IV for assistance.

23 May 1989 in the cotton plots, and on 1 June 1988 and 14 June 1989 in the soybean plots. Midseason nematode counts were taken on 11 July 1988 and 13 July 1989 in cotton, and on 29 July 1988 and 25 July 1989 in soybean. Final nematode numbers were determined, and the center two rows of each plot were mechanically harvested on 9 November 1988 and 14 November 1989 in cotton, and on 27 October 1988 and 16 October 1989 in soybean.

For nematode assays, 12 individual soil cores (2.5 cm d, 20 cm deep) were collected in a systematic pattern from the center two rows of each plot and bulked. Plant-parasitic nematodes were extracted from 500 cm^3 soil by elutriation and sucrose centrifugation (approximate extraction efficiency = 0.20) (2) and counted. In the midseason and harvest nematode assays, roots were collected from the eluted 500-cm^3 sample of soil from each plot and incubated on a mist extractor at 26 C for 48 hours (2). Root counts were added to soil counts for further analyses. Nematode numbers were reported per 100 cm^3 soil. All plots were managed by standard practices recommended for the area and irrigated as needed with lateral overhead irrigation. Alleys were planted and managed along with the plots to remove border effects.

Statistical analysis: An inverse-logistic function was used to represent the nematode damage function as $Y = m + ([M - m]/[1 + (P/u)^b])$, where Y represented crop yield, P was either early season nematode density (Pi) or midseason density (Pm), M was maximum yield, m was minimum yield, and u and b together determined shape and location of the resulting curve (17). Nematode population changes during the growing season were represented by an increasing exponential function $P = M(1 - e^{-b \cdot Pi})$, where P was Pf, final nematode population density, or Pm, midseason population density, Pi was early season population density, M was the maximum population density, and b determined the exponential rate of increase (17). Damage functions and nematode reproductive curves were fitted to frequency class means constructed from nematode counts and yield data (6,17) after combining grids and years, using nonlinear regression analysis (19).

Results and Discussion

The models selected to describe damage functions and reproductive curves fit the data well and offered suitable biological interpretations for host–parasite relationships. Mean-square-errors were less than 0.05 of total-sums-of-squares for all functions (data not shown), and standard errors of parameter estimates were within acceptable limits (Tables 1,2).

Damage functions indicated maximum yield suppressions of 18% on cotton and 48% on soybean over the range of early season *H. columbus* densities (Pi) included in this study (Table 1) (Fig. 1A,E). Similar functions indicated maximum yield suppressions of 38% on cotton and 30% on soybean in response to midseason nematode population densities (Pm) (Table 1) (Fig. 1B,F). Midseason nematode population densities influenced cotton yields more than early season densities, whereas

TABLE 1. Parameter estimates and standard errors for *Hoplolaimus columbus* damage functions on cotton cv. Deltapine 90 and soybean cv. Gordon.

	Yield–Pi		Yield–Pm	
Parameter†	Estimate	Standard error	Estimate	Standard error
	Cotton lint kg/ha			
M	862.3	10.3	876.8	10.3
m	704.8	31.0	543.0	87.6
u	68.4	12.2	269.7	44.3
b	5.7	4.7	4.7	2.4
	Soybean seed kg/ha			
M	2,472.9	217.0	2,439.7	146.0
m	0.0	0.0	1,701.9	57.6
u	373.9	187.4	35.4	11.2
b	0.47	0.17	4.4	3.8

† Parameters fitted by nonlinear regression to data using the model $Y = m + ([M - m]/[1 + (P/u)^b])$, where Y was crop yield, P was either early season (Pi) nematode density per 100 cm^3 soil or midseason (Pm) density per 100 cm^3 soil, M represented maximum yield, m represented minimum yield, and u and b together determined shape and location of the resulting curve.

TABLE 2. Parameter estimates and standard errors for *Hoplolaimus columbus* reproductive functions on cotton cv. Deltapine 90 and soybean cv. Gordon.

	Pm/Pi		Pf/Pi	
Parameter†	Estimate	Standard error	Estimate	Standard error
		Cotton		
M	321.2	51.7	122.9	5.0
b	0.009	0.002	0.054	0.009
		Soybean		
M	532.6	55.1	474.0	36.0
b	0.009	0.002	0.02	0.004

† Parameters fitted by nonlinear regression to data using the model $P = M(1 - e^{-b \cdot Pi})$, where *P* was Pf, final nematode population density, or Pm, midseason population density, Pi was early season population density, *M* represented the maximum population density, and *b* determined the exponential rate of increase. *Hoplolaimus columbus* densities were expressed per 100 cm^3 soil.

soybean yields were more strongly influenced by early season *H. columbus* population densities. The best-fit model for soybean yield–Pi converged with a calculated minimum yield of zero (Table 1), which reduced the model to a simpler negative exponential form. This result suggested that the yield response had not reached a minimum for soybean, and further suppression could be expected at higher Pi. The soybean yield response did reach a minimum with respect to increasing midseason population densities (Fig. 1F), probably because relatively rapid reproduction by *H. columbus* on soybean had diminished differences among plots by midseason.

Estimates of yield losses in this study were within ranges previously reported for *H. columbus* on cotton (14,17) and soybean (1,4,11,12,17,18). The damage function for cotton cv. Deltapine 90 reported herein was similar to that previously reported for cotton cv. Coker 315 in North Carolina (17), with respect both to the shape of the curve and to the parameter estimates. Soybean cv. Centennial was not as sensitive in the previous report as Gordon was in this study. In another study, however, Gordon and Centennial appeared to be equally intolerant to *H. columbus* (20), as compared with treatments that included a nematicide. Damage functions cannot be generalized among soybean cultivars, since two- to threefold differences in tolerance to *H. columbus* have been reported (4,13,18,20). Variability in growing seasons and soil characteristics also would cause differences in damage relationships. The strong response of Gordon to early season nematode densities may be related to suppression of nodulation and (or) nitrogen fixation, as has been reported for other plant-parasitic nematode species (7–9). Higher nematode population densities at midseason would not be as damaging, because nodules would already be formed on soybean roots.

There was a very strong relationship between Pf and Pi on cotton for *H. columbus* Pi densities less than 50/100 cm^3 soil, but at higher Pi densities the reproductive curve reached an asymptotic maximum for Pf at approximately 123/100 cm^3 soil (Table 2) (Fig. 1C). In contrast, Pm increased as a function of Pi throughout the range of early season densities, to a projected maximum of 321/100 cm^3 soil (Table 2) (Fig. 1D). Nematode populations were still increasing on the vigorous plants at midseason, whereas by harvest the plants were declining and counts had stabilized. The contrasts between Pf and Pm reproductive curves for soybean were similar to the cotton curves, except that numbers of nematodes were higher at both sampling dates for soybean. The Pf/Pi curve reached a maximum at Pi densities four times greater than on cotton (200/100 cm^3 soil) (Table 2) (Fig. 1G,H). These relationships, combined with the damage functions, indicated that soybean was a better host than cotton but also was more sensitive in terms of yield suppression.

The mean Pi on cotton was 46, increasing 54% to a mean Pf of 71/100 cm^3 soil. The mean Pi on soybean was 66, increasing 367% to 308/100 cm^3 soil. The percentage increase and the maximum population density reported in this study on cotton cv. Deltapine 90 was lower than previously reported from North Carolina on cotton cv. Coker 315 (190% increase to 182/100 cm^3 soil) (17). The form of the

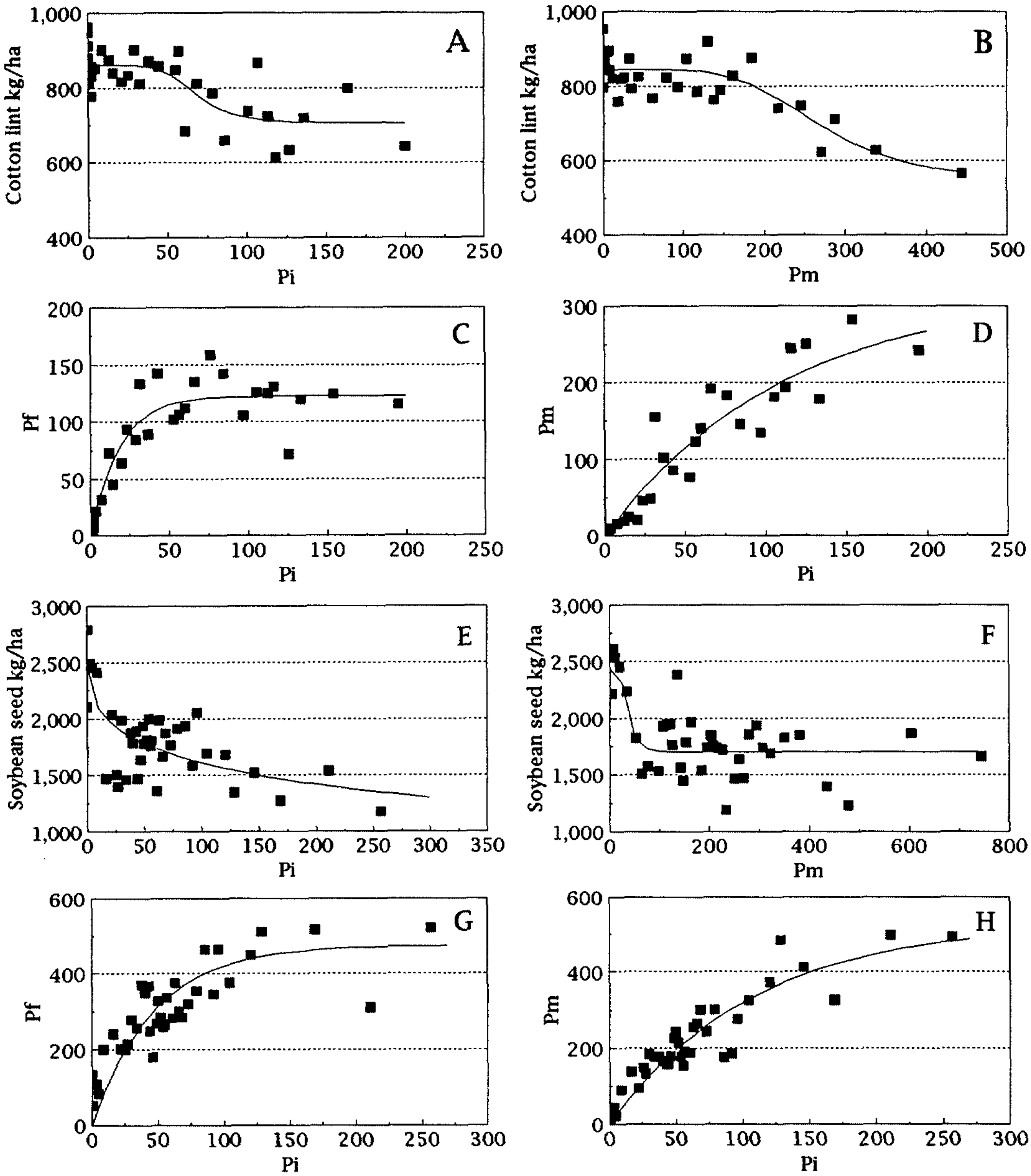

FIG. 1. Host–parasite relationships of *Hoplolaimus columbus* on cotton (A–D) and soybean (E–H). A) Yield versus early season nematode population densities (Pi). B) Yield versus midseason nematode population densities (Pm). C) Harvest nematode population densities (Pf) versus early season densities. D) Midseason nematode population densities versus early season densities. E) Yield versus early season nematode population densities. F) Yield versus midseason nematode population densities. G) Harvest nematode population densities versus early season densities. H) Midseason population densities versus early season densities. Parameter estimates for fitted curves in Tables 1 and 2. Each data point represents the frequency-class mean of four plots. $N = 144$ plots. *Hoplolaimus columbus* densities are per 100 cm^3 soil.

reproductive function was quite similar between the two studies, however, after accounting for differences in scale. In contrast, percentage increases in nematode density and maximum population levels were much higher in this study for soybean cv. Gordon than previously reported for Centennial (17). In the North Carolina study, however, the highest Pi levels on soybean were nearly twice those reported herein. Higher *H. columbus* population densities at planting may have stunted soybean growth to the extent that reproduction of these obligate parasites was limited by reduced availability of photosynthates and smaller root systems.

Damage functions can be used to predict yield suppression and to calculate economic thresholds. A 10% reduction in cotton yield would be predicted at a Pi of 70 *H. columbus*/100 cm^3 soil, whereas a Pm of 220 would be required to predict a similar yield suppression. The economic threshold for a nematicide that cost $72/ha ($30/A) would be 60 *H. columbus*/100 cm^3 soil, assuming a price for cotton lint of $1.44/kg ($0.60/lb). A 10% reduction in soybean yield would be predicted at a Pi of 4, whereas a Pm of 30 would be predictive of a similar decrease. Application of a control measure that cost $72/ha would not be economically feasible with an assumed price of $0.04/kg ($5.50/bu) soybean seed. A return of $0.065/kg seed ($9.36/bu) would be required for the treatment to be profitable at the highest Pi included in formulation of the damage function (260 *H. columbus*/100 cm^3 soil). It also is apparent from examination of reproductive curves that cotton following soybean may not be an advisable cropping sequence in areas infested with *H. columbus*. However, because nonhost crops are not commonly grown within infested areas of Georgia, growers typically use a soybean–cotton sequence and must rely instead on the use of nematicides on cotton.

These results provided an illustration of the potential utility of damage functions. Although the midseason damage functions are not useful to a grower in terms of implementing control measures for the current crop, they add to our understanding of the system and may be useful in projecting yield suppression for other purposes. The reproductive curves, likewise, provided valuable information on cropping-system dynamics, and, when combined with data on other crops, they may suggest suitable crop rotations. As additional data become available, more generalized host–parasite relationships will be characterized, ultimately leading to the development of improved management decision tools.

Literature Cited

1. Appel, J. A., and S. A. Lewis. 1984. Pathogenicity and reproduction of *Hoplolaimus columbus* and *Meloidogyne incognita* on Davis soybean. Journal of Nematology 16:349–355.

2. Barker, K. R. 1985. Nematode extraction and bioassays. Pp. 19–35 *in* K. R. Barker, C. C. Carter, and J. N. Sasser, eds. An advanced treatise on *Meloidogyne*, vol. 2: Methodology. Raleigh: North Carolina State University Graphics.

3. Blackmon, C. W. 1980. Control of the Columbia lance nematode on cotton. Fungicide and Nematicide Tests 35:227.

4. Boerma, H. R., and R. S. Hussey. 1984. Tolerance to *Heterodera glycines* in soybean. Journal of Nematology 16:289–296.

5. Duncan, L. W. 1991. Current options for nematode management. Annual Review of Phytopathology 29:469–490.

6. Ferris, H. 1984. Nematode damage functions: The problem of experimental and sampling error. Journal of Nematology 16:1–9.

7. Germani, G., J. Mugnier, and Y. Dommergues. 1984. Influence of pathogenic nematodes on nodulation and seed yield of soybeans in Senegal. Revue de Nématologie 7:335–340.

8. Hussey, R. S., and K. R. Barker. 1976. Influence of nematodes and light sources on growth and nodulation of soybean. Journal of Nematology 8:48–52.

9. Ko, M. P., K. R. Barker, and J. S. Huang. 1984. Nodulation of soybeans as affected by half-root infection with *Heterodera glycines*. Journal of Nematology 16:97–105.

10. Kraus-Schmidt, H., and S. A. Lewis. 1981. Dynamics of concomitant populations of *Hoplolaimus columbus, Scutellonema brachyurum,* and *Meloidogyne incognita* on cotton. Journal of Nematology 13:41–48.

11. Lewis, S. A., F. H. Smith, and W. M. Powell. 1976. Host–parasite relationships of *Hoplolaimus columbus* on cotton and soybean. Journal of Nematology 8:141–145.

12. Mueller, J. D., and G. B. Sanders. 1987. Control of *Hoplolaimus columbus* on late-planted soybean with aldicarb. Supplement to the Journal of Nematology 19:123–126.

13. Mueller, J. D., D. P. Schmitt, G. C. Weiser, E. R. Shipe, and H. L. Musen. 1988. Performance of soybean cultivars in *Hoplolaimus columbus* infested fields. Supplement to the Journal of Nematology 20:65–69.

14. Mueller, J. D., and M. J. Sullivan. 1988. Response of cotton to infection by *Hoplolaimus columbus*. Supplement to the Journal of Nematology 20:86–89.

15. Noe, J. P. 1988. Crop loss assessment in nematology. Pp. 85–99 *in* M. C. Saxena, R. A. Sikora, and J. P. Srivastava, eds. Nematodes parasitic to cereals and legumes in temperate semi-arid regions. Aleppo,

Syria: International Center for Agricultural Research in the Dry Areas (ICARDA).

16. Noe, J. P. 1990. Efficacy of fumigant nematicides to control *Hoplolaimus columbus* on cotton. Supplement to the Journal of Nematology 22:718–723.

17. Noe, J. P., J. N. Sasser, and J. L. Imbriani. 1991. Maximizing the potential of cropping systems for nematode management. Journal of Nematology 23:353–361.

18. Nyczepir, A. P., and S. A. Lewis. 1979. Relative tolerance of selected soybean cultivars to *Hoplolaimus columbus* and possible effects of soil temperature. Journal of Nematology 11:27–31.

19. SAS Institute. 1987. SAS/STAT guide for personal computers, 6th ed. Cary, NC: SAS Institute.

20. Schmitt, D. P., and J. L. Imbriani. 1987. Management of *Hoplolaimus columbus* with tolerant soybean and nematicides. Supplement to the Journal of Nematology 19:59–63.