Host Plants, Distribution, and Ecological Associations of Hoplolaimus columbus[1]

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Abstract: Selected species and cultivars of plants were evaluated for host suitability for *Hoplolaimus columbus* under greenhouse and field conditions. Sixteen agronomic plant cultivars were assayed for infection and reproduction after 2-6 months. Lima bean, soybean, cotton, and sweet corn were most favorable for nematode reproduction, whereas sweet potato was a nonhost plant. Field corn and watermelon, which tolerated *H. columbus* without significant yield losses, are suited for alternative crops in the southern coastal plain. Populations of *H. columbus* occurred in 15% of soybean and 25% of cotton soil samples assayed. Population levels of *H. columbus* and *Helicotylenchus* spp. were correlated with fluctuations in various soil nutrient factors, whereas *Meloidogyne* spp. and *Scutellonema* spp. were not. No correlation was detected between the presence of *H. columbus* and populations of other nematode genera studied. *Key Words:* lance nematode, parasitism, host-parasite relations, ecology.

The pathogenicity of *Hoplolaimus columbus* Sher on soybean and its parasitism on cotton have been demonstrated (12). Other agronomic, horticultural, and weed species have been reported as hosts of *H. columbus* (1, 7, 9, 11). Among these hosts are wheat *(Triticum aestivum)*, corn *(Zea mays)*, lima bean *(Phaseolus lunatus)*, watermelon (*Citrullus lanatus)*, and purple nutsedge (*Cyperus rotundus* L.), all of which are common in the southern coastal plain.

The objectives of this study were: *(i)* to determine if many regionally-grown, crop plants are hosts of *H. columbus; (ii)* to evaluate potential alternative crops under field conditions; and *(iii)* to characterize the regional distribution of *H. columbus* and its association with various biological and edaphic factors.

MATERIALS AND METHODS

Host studies: The host suitability of 14 cultivars of 9 crop species was tested in the field and greenhouse. The crops chosen are widely grown on southern coastal plain soils and might serve as alternatives to the soybean-cotton cropping system. Three cultivars of soybean [*Glycine max* (L.) Merr.], three of cotton (*Gossypium hirsutum* L.), two of Southern pea [*Vigna unguiculata* (L.) Walp.], and one each of watermelon (*Citrullus lanatus* Schrad.), cantaloupe (*Cucumis melo* L.), sweet potato (*Ipomoea batatas* L.), cucumber (*Cucumis sativus* L.), field corn and sweet corn (*Zea mays* L.) were evaluated in 1973 and 1974. Average temperatures (at a depth of 10 cm) at the field test site in 1973 were 16.9, 21.2, 26.0, 27.9, 27.8, and 26.9 C April to September, respectively. Average temperatures for the same period in 1974 were 19.1, 23.9, 25.9, 26.7, 27.7, and 26.3 C. Monthly total precipitation in 1973 for April through September was 8.9, 7.0, 27.0, 15.3, 9.7, 12.0 cm; and in 1974, 8.3, 11.1, 10.2, 15.0, 18.0, and 14.2 cm, respectively. An experimental field with a history of soybean and cotton crops was selected at the Edisto Experiment Station, Blackville, S.C. Cocklebur (*Xanthium pennsylvanicum* L.) and purple nutsedge (*Cyperus rotundus*) are common in this geographical region and were present in the experimental plots. Cocklebur is not a host for *H. columbus*, whereas nutsedge is a host (1, 7). Low populations of *Trichodorus porosus*, *Helicotylenchus dihystera*, and *Criconemoides curvatum* were present in portions of the test area. Twenty soil samples of 5-10 cores each were collected at the 0.4-ha experimental plot. A P_i of 200 ± 35 *H. columbus*/100 cm^3 was found 10 days before the test crops were planted.

The field experiment contained six replicates in a split-plot design. Crop cultivars were main plots and one-half of each plot (subplot) was treated with 1,2-dibromo-3, chloropropane (DBCP) at 10 kg (a.i.)/ha. The entire test area was subsoiled under the row prior to planting the crops. Treated subplots received fumigant at a depth of

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18 cm directly behind the subsoil shank in the row. Guard rows separated each subplot, and 6-m alleys lay between replicates. Yields among cultivars and fumigation treatments were compared, and randomly selected plants collected at midseason and prior to harvest were examined for the presence of *H. columbus* in the roots. The roots were stained in acid fuchsin-lactophenol, and nematode counts were made on five, 10-cm root pieces from each plant. Nematode numbers were recorded in soil samples taken from 8 cultivars in 1974 and 13 cultivars in 1973 at midseason and 2 weeks prior to harvest for some of the crops tested each year.

Greenhouse experiments were conducted in conjunction with the field tests. Six replicates of each of 14 cultivars of 9 crop species, with and without added populations of *H. columbus,* were grown in 5-liter glazed crocks in pasteurized Varina sandy loam from the site of the field studies. Nematodes for inoculum were extracted by centrifugal flotation, and 38 (juveniles and adults)/100 cm^3 of soil were added to six crocks/cultivar. Plants were grown for 75-180 days at an ambient temperature of 25-35 C. The number of nematodes in five, 10-cm root pieces from each cultivar at the end of the experiment were used as one of the criteria for determining host suitability. Root sections of field and greenhouse plants were rated 0, 1, 2, or 3 if the sections contained 1, 1-3, 4-7, or more than 7 nematodes, respectively,/10-cm section. Root sections were randomly chosen from the middle portion of the root system. Numbers of nematodes/100 cm^3 of mixed soil and the fresh weight of plant shoots also were recorded. Reproductive factors [final population density (P_f)/initial population density (P_i)] were calculated (15).

Nematode survey: Soil samples sent to the Clemson University Plant Problem Clinic for nematode analysis in 1974 were analyzed for nutrient status and phytoparasitic nematodes. Data were analyzed for nematode genera (% occurrence), relation of *H. columbus* to soil nutrient factors, relation of *H. columbus* populations with those of other genera, and frequency of *H. columbus* infestations in various crops.

RESULTS

Host studies—greenhouse: Hoplolaimus columbus reproduced on all crops tested with the exception of sweet potato. 'Henderson' bush lima bean and 'Lockett' cotton were excellent hosts since the reproductive factor (R) was over 7.0 (Table 1). Cultivars with an R of 3.0-7.0 that rated as good hosts were 'Coker 201' cotton; 'Coker 4504, 'Hardee', and 'Bragg' soybeans; 'Golden Queen' sweet corn, 'Pioneer 3369A' field corn;

TABLE 1. Host sensitivity and related reproduction of *Hoplolaimus columbus.*

Plant and cultivar	Fresh top weight (gm) With nematodes	Fresh top weight (gm) No nematodes	Reproductive factor[a]
Soybean			
Bragg	34.5*[b]	45.9	3.4
Coker 4504	36.4	41.3	4.3
Hardee	42.1	37.3	3.5
Cotton			
Deltapine-16	41.0	55.2	2.0
Coker 201	55.9	57.5	4.4
Lockett	44.8	41.5	7.4
Sweet corn			
Golden Queen	160.0	140.6	3.4
Field corn			
Pioneer 3369A	—	—	3.2
Cantaloupe			
Edisto	45.8	43.5	3.3
Cucumber			
Ashley	75.3	66.0	1.5
Watermellon			
Charleston Grey	58.9	54.8	2.7
Southern pea			
Big Boy	81.5	99.5	1.7
Mississippi Silver	79.7*	114.0	3.4
Lima bean			
Henderson	52.5	38.5	9.3
Sweet potato			
Jewel	83.3	85.0	0.6

[a]Reproductive factor = P_f/P_i; P_i = 38 ± 5 nematodes/100 cm^3 (P_f = final population density; P_i = initial population density).

[b]Asterisk (*) indicates top weight significantly different from treatments receiving no nematodes (P = 0.05).

'Mississippi Silver' southern pea; and 'Edisto' cantaloupe. Cultivars with an R of less than 3.0 that rated as poor hosts included 'Charleston Gray' watermelon and 'Big Boy' southern pea. 'Deltapine-16' cotton and 'Ashley' cucumber had an R of less than 2.0. 'Jewel' sweet potato was not a host for *H. columbus*. Nematode parasitism suppressed the shoot growth of 'Bragg' soybean and 'Mississippi Silver' southern pea, whereas the shoot growth of other hosts were not affected.

Host studies–field: Soybean and sweet corn (Golden Queen) supported highest nematode population levels at the time of harvest in experiments conducted in 1973 and 1974 (Table 2). Cotton, field corn, and 'Mississippi Silver' southern pea supported a substantial increase in nematode numbers and were therefore considered good hosts. Cantaloupe, watermelon, and cucumber were fair to poor hosts. Sweet potato was a nonhost.

Compared to the yield of control plots, yield increases after soil fumigation varied between years and among crops. Fumigation with DBCP effected greater yields of 'Hardee' soybean in 1973 and 1974, but an increase in 'Bragg' was noted only in 1974 (Table 2). Deltapine-16 cotton, sweet corn,

TABLE 2. Growth and yield of certain vegetables and field crops as affected by *Hoplolaimus columbus* and soil fumigation.

					No. nematodes/100 cm³ soil			
			Yield (kg/plot)		Midseason		Harvest	
Crop	Cultivar	Treatment	1973	1974	1973	1974	1973	1974
Watermelon	Charleston Grey	F	44.6	72.2	—	—	243	25
		NF	46.4	72.9	—	—	166	43
Cucumber[b]	Ashley	F	12.7	60.2	—	—	158	30
		NF	8.4	63.6	—	—	242	144*
Cantaloupe[b]	Edisto	F	—	27.2*	—	—	140	42
		NF	—	14.1	—	—	208	66
Southern pea	Big Boy	F	0.6	6.2	—	—	220	160
		NF	0.3	5.7	—	—	209	182
	Mississippi Silver	F	0.5	12.4*	—	—	342	196
		NF	0.6	7.2	—	—	380	240
Sweet potato	Jewel	F	11.5	10.9	—	—	59	36
		NF	11.9	9.6	—	—	29	56
Soybean	Bragg	F	1.2	5.2*[c]	—	280	790	290
		NF	1.1	3.7	—	437	778	369
	Hardee	F	2.5	3.7*	—	172	689	271
		NF	0.8	3.3	—	222	605	387
	Coker 4504	F	1.5	—	—	—	625	—
		NF	1.0	—	—	—	416	—
Cotton	Deltapine-16	F	0.3	4.7*	196	54	244	243
		NF	0.2	3.1	279	115	338	197
	Coker 310	F	0.2	4.8	157	25	384	173
		NF	0.2	3.6	177	83	373	144
	Lockett	F	0.1	—	290	—	363	—
		NF	0.1	—	318	—	320	—
Field corn	Pioneer 3369 A	F	3.7	—	202	—	301	—
		NF	4.4	—	249	—	209	—
Sweet corn	Golden Queen	F	3.0*	—	425	—	412	—
		NF	1.4	—	563	—	638	—

[a]Nonfumigated soil (NF) or fumigated with DBCP, 10 kg (a.i.)/ha (F).
[b]Number of fruits/replicate in F treatments were significantly higher (P = 0.05) than NF treatments for cucumbers 1973 and for cantaloupes. Cantaloupes not harvested in 1973 due to insect damage.
[c]Asterisk (*) indicates fumigated plot yield significantly greater than that of nonfumigated plot (P = 0.05).

cantaloupe, and Mississippi Silver southern pea also produced significantly greater yields in fumigated soil. Yields of field corn, watermelon, two cotton cultivars, and sweet potato did not increase significantly in fumigated soil.

Correlation between the numbers of *H. columbus* in mid- or late season and yield response to fumigation lacked consistency. Significant yield increases occurred in some soybean cultivars after fumigation but were not always correlated with a decrease in lance nematodes. The yield response of Deltapine-16 cotton, however, was accompanied by significantly fewer nematodes in the fumigated than in the nonfumigated soil.

Nematode survey: Of 372 soybean soil samples received from throughout the state, 56 (15%) contained *H. columbus.* All 56 of these originated from the middle and upper coastal plain of South Carolina. Spiral nematodes, (*Helicotylenchus* sp.), were present in 66% and *Meloidogyne* sp. in 15% of the samples. One-half of the soybean samples containing *H. columbus* also had spiral nematodes with a mean population of 112/100 cm^3 of soil. The mean pH of all soybean samples was 5.8, but those that contained *Meloidogyne* sp. or *H. columbus* averaged 5.6. Samples from soybean fields containing *Meloidogyne* sp. had a higher percentage of phosphorus deficiency than samples without *Meloidogyne* sp.

Twenty-five percent of cotton samples had *H. columbus,* whereas 56% contained *Helicotylenchus* sp. Thirty-three percent of the cotton samples with *H. columbus* also had a population of *Helicotylenchus* sp. averaging 66 nematodes/100 cm^3 of soil.

A number of samples from cotton and soybean fields were infested with both *H. columbus* and *Meloidogyne* sp. Where *H. columbus* was predominant, root-knot nematodes were found in 7.1 and 8.9% of the samples from each crop, respectively. In samples with root-knot nematode as the predominant form, *H. columbus* was present in 18.7 and 8.5% of the samples, respectively. When present in root-knot infested soil, *H. columbus* had a mean population level of 125.4/100 cm^3 of soybean field soil samples and 131.0/100 cm^3 of cotton field soil samples submitted for analysis. *Helicotylenchus* spp. and *Scutellonema brachyurum* were the most frequent concomitant genera found in *H. columbus*-infested soil (Table 3).

Populations of *H. columbus* in cotton and soybean samples tended to increase as the pH and phosphorus increased and to decline as the potassium and magnesium increased (Table 4). *Hoplolaimus columbus* populations in cotton and soybean samples were negatively correlated with potassium (P = 0.01). Relationships among population densities of *H. columbus* and soil factors occured in four out of five factors examined (P = 0.05). Populations of *Helicotylenchus* spp. declined in relation to increases in the unit value of phosphorus. No responses to soil factors were noted among other genera.

Nutrient factors in soil containing the various nematode genera were fitted to a nematode-population predictive equation. This equation for the dependent-variable nematode = intercept value + nematode density change (ΔND)/*unit* value change of pH + $\Delta ND/\Delta P_2O_5$ + $\Delta ND/\Delta K^+$ + $\Delta ND/\Delta Ca^{++}$ + $\Delta ND/\Delta Mg^{++}$. The reliability of this equation for prediction of nematode numbers, as indicated by the R^2 value, is rather low. However, several nutrient factors were of greater value, as indicated by degree of significance in the equation than other independent variables.

DISCUSSION

Hoplolaimus columbus is associated with poor growth of soybean and cotton in the coastal plain of South Carolina and Georgia (8, 13). Interpretation of data collected from our field experiments suggests that cotton growth is suppressed by *H. columbus.* Field corn and watermelon appear suitable as alternate crops for soybean and cotton since the tested varieties were tolerant to *H. columbus.* On field corn, however, this nematode increased and stabilized at a density which damages susceptible crops. Therefore, if soybean were planted where field corn grew previously, expected nematode numbers would likely cause harm. A third cropping alternative, sweet potato, did not support reproduction of *H. columbus* and has promise for reducing populations of this nematode.

TABLE 3. Populations of plant-parasitic nematodes commonly associated with *Hoplolaimus columbus* in soybean and cotton.

Nematode	Nematodes/100 cm³ soil		*H. columbus* samples with concomitant genera (percentage)	
	Soybean	Cotton	Soybean	Cotton
Hoplolaimus columbus	138.8	186.2	100.0	100.0
Helicotylenchus sp.	87.2	79.8	52.8	33.3
Criconemoides sp.	24.0	53.2	26.4	21.4
Scutellonema sp.	93.0	50.2	37.7	47.6
Meloidogyne sp.	65.1	105.0	8.9	7.1

In contrast to the effects of fumigation reported by Cohoon (5), fumigation with DBCP effected greater yield of cantaloupe in our tests. Watermelon exhibited tolerance to *H. columbus* in these experiments and in those of Cohoon (6). These results are confirmed by others (3, 17) who obtained increased yields of cotton and soybean on soil treated with DBCP. The beneficial effect from fumigation was greater in years when water stress occurred.

Field and greenhouse experiments were similar in R values obtained. Cantaloupe, however, was a poor host in the field and a good host in greenhouse trials; whereas, Deltapine-16 cotton was a poor host in the greenhouse and a good host in field experiments. These data support the work of Fassuliotis (7) with regard to reproductive factors obtained. There is a divergence in classification of host status for watermelon and cantaloupe, however. The reproductive factor for watermelon is similar in both experiments, but it is rated as a good host in the previous study. The variance in results obtained with cantaloupe may be a function of variety. Population response of *H. columbus* to cantaloupe grown in the greenhouse and its response in field experiments differed in 1974 and were similar in 1973. In general, the cucurbits were hosts for *H. columbus* but did not evoke an increase in population densities similar in magnitude to the legumes, cotton, and corn.

Only two cultivars ('Mississippi silver' southern pea and 'Bragg' soybean) grown

TABLE 4. Relationships of unit value changes in soil variables to nematode populations on crops for coastal plain soils as measured by multiple regression.

Nematode	Host	Intercept[a]	Regression coefficients[b]					R-square (%)
			pH	P_2O_5	K^+	Ca^{++}	Mg^{++}	
Hoplolaimus columbus	Soybean	— 598	132*	15	—29*	3	—11	33.8
	Cotton	236	9	—10	—14	—37	—58	46.8
	Both	— 201	58*	17**	—23**	0	—20*	24.1
Meloidogyne spp.	Soybean	— 145	44	5	— 0	—13	22	16.9
	Cotton	—1235	235	4	0	10	—37	29.7
	Both	39	39	— 2	12	—12	6	20.5
Helicotylenchus spp.	Soybean	152	5	— 9	— 3	4	— 8	5.2
	Cotton	218	—5	— 9	— 3	11	—19	10.7
	Both	168	3	— 9*	— 3	6	—10	6.6
Scutellonema sp.	Soybean	51	5	13	— 7	3	— 0	6.6
	Cotton	— 102	43	— 9	10	—13	8	6.6
	Both	14	21	4	— 5	— 3	3	2.5

[a]Constant calculated by drawing straight line, using least squares procedure, through the data points to the y-axis.

[b]Significant (*P* = 0.05, *; 0.01, **) improvement in prediction model when adding this independent variable to equation which includes all other independent variables.

in the greenhouse were affected by *H. columbus*. Yields of other soybean and cotton cultivars were not affected. Possible reasons include: the greenhouse-grown plants may have completed rapid growth before nematode populations increased to damaging levels, the plants were not stressed by excess or lack of moisture and nutrients, and P_i might have been low.

Populations of *Helicotylenchus* sp. and *Scutellonema brachyurum* are common when *H. columbus* is present in cotton and soybean. These species may have an additive or synergistic effect with *H. columbus* on these crops. The association of *H. columbus* and *Meloidogyne* sp. is not uncommon, and competition between these species has been documented (2).

In a six-county survey conducted in 1975, *Helicotylenchus* spp. were often found in numbers exceeding 500/100 cm^3 of soil and 200/gm dry weight of soybean root (Lewis, unpublished). *Helicotylenchus dihystera* has been found in roots of 'Lee' soybean, but this species may not suppress soybean yields when it acts alone (16). Further experiments with this species and *Scutellonema* at higher inoculum levels in single and concomitant populations with *H. columbus* are needed.

Simple linear correlations were useful in evaluating single factors in the soil environment. When the effects of all nutrients in the group were evaluated as multiple regression coefficients, other relationships among the nutrients became evident. Several nematode-nutrient relationships were evident in samples containing *H. columbus*, one was evident in samples containing *Helicotylenchus*, and none were evident in samples with *Scutellonema* and *Meloidogyne*. Burns (4) noted greater numbers of *Pratylenchus alleni* in roots of soybean at pH 6.0 than in roots of plants grown at pH 4.0 or 8.0. She found that more Tylenchinae-Psilenchinae and *H. galeatus* were recovered at pH 6.0 than at pH 4.0 or 8.0. Similarly, numbers of *H. columbus* recovered from our soil samples increased as pH rose to approximately 6.8. Reported correlations of nematodes and pH in soybean fields were negative except for *Helicotylenchus pseudorobustus*, which was positive (14). Correlations found by others with different nematode species have been variable. The prediction model in this study was useful in assessing the importance and reliability of pH and several elements. The interaction of chemical and physical characteristics of soil may account for the limited geographical range of *H. columbus*.

LITERATURE CITED

1. BIRD, G. W., and CH. HÖGGER. 1973. Nutsedges as hosts of plant parasitic nematodes in Georgia cotton fields. Plant Dis. Rep. 54: 402.
2. BIRD, G. W., O. L. BROOKS, and C. E. PERRY. 1974. Dynamics of concomitant field populations of Hoplolaimus columbus and Meloidogyne incognita. J. Nematol. 6:190-194.
3. BLACKMON, C. W., and H. L. MUSEN. 1974. Control of the Columbia (lance) nematode Hoplolaimus columbus on soybeans. Plant Dis. Rep. 58:641-645.
4. BURNS, N. C. 1971. Soil pH effects on nematode populations associated with soybeans. J. Nematol. 3:238-245.
5. COHOON, D. F. 1974. Chemical control of Hoplolaimus columbus on Edisto cantaloupe. *in* Fungicide and Nematicide Tests—Results of 1974. Am. Phytopathol. Soc. 30:161-162.
6. COHOON, D. F. 1974. Chemical control of Hoplolaimus columbus on 'Charleston Gray' watermelon. *In* Fungicide and Nematicide Tests-Results of 1974. Am. Phytopathol. Soc. 30:177.
7. FASSULIOTIS, G. 1974. Host range of the Columbia lance nematode Hoplolaimus columbus. Plant Dis. Rep. 58:1000-1002.
8. FASSULIOTIS, G., G. J. RAU, and F. H. SMITH. 1968. Hoplolaimus columbus, a nematode parasite associated with cotton and soybean in South Carolina. Plant Dis. Rep. 52:571-572.
9. HÖGGER, CH. H., and G. W. BIRD. 1974. Weeds and covercrops as overwintering hosts of plant parasitic nematodes of soybean and cotton in Georgia. J. Nematol. 6:142 (Abstr.).
10. JENKINS, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692.
11. LEWIS, S. A., F. H. SMITH, and C. W. BLACKMON. 1974. Host range, distribution, and control of Hoplolaimus columbus. J. Nematol. 6:145 (Abstr.).
12. LEWIS, S. A., F. H. SMITH, and W. M. POWELL. 1976. Host-parasite relationships of Hoplolaimus columbus on cotton and soybean. J. Nematol. 8:141-145.
13. MOTSINGER, RALPH E., J. L. CRAWFORD, and S. S. THOMPSON. 1975. Survey of cotton and soybean fields for lance nematodes in East Georgia. Plant Dis. Rep. 58:369-372.
14. NORTON, D. C., L. R. FREDERICK, D. E. PONCHILLIA, and J. W. NYHAN. 1971. Correlations of nematodes and soil properties in soybean fields. J. Nematol. 3:154-163.
15. OOSTENBRINK, M. 1966. Major characteristic

of the relation between nematodes and plants. Meded. Landbouwhogesch. Wageningen 66(4), 46 pp.
16. ORBIN, D. P. 1973. Histopathology of soybean roots infected with Helicotylenchus dihystera. J. Nematol. 5:37-40.
17. PARKER, M. B., N. A. MINTON, O. L. BROOKS, and C. E. PERRY. 1975. Soybean yield and lance nematode population as affected by subsoiling, fertility, and nematicide treatments. Agron. J. 67:663-666.