Incidence of Plant-Parasitic Nematodes in the Coastal Plain of North Carolina

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ABSTRACT

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Fields (800) in the coastal plain of North Carolina were systematically selected and sampled. Corn and soybeans were the dominant crops. Nematode genera occurring in about 50% or more of the fields were *Criconemella, Helicotylenchus, Meloidogyne, Pratylenchus,* and *Tylenchorhynchus.* Of the *Meloidogyne* spp. coming from 401 fields, 31% reproduced on NC-95 tobacco (*M. arenaria, M. javanica,* races 2 and 4 of *M. incognita,* and *M. hapla*), 17% reproduced on peanut (*M. arenaria* race 1 and *M. hapla*), and 15% reproduced on cotton (races 3 and 4 of *M. incognita*). *Heterodera glycines* was present in 25% of the fields sampled. This nematode was detected in 34% of the soybean fields and in 16% of fields planted with nonhosts. Sixty percent of the infested fields contained *H. glycines* races that could not be managed with resistant cultivars. The specific geographic spatial patterns of nematodes were associated with cropping patterns.

Additional key words: crop loss, distribution, ecology

Most of our knowledge about the geographic spatial patterns of plant-parasitic nematodes within North Carolina has been gained through assays of samples from problem fields sent through the N.C. Agricultural Extension Service, the N.C. Department of Agriculture's Nematode Advisory Service, and data from research files (11). *Tylenchorhynchus, Meloidogyne,* and *Paratrichodorus* were the most widespread genera in the coastal plain as determined in an experimental nematode advisory program in 1974 (1). *Pratylenchus* (mixtures of *P. zeae* Graham, *P. brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven, and *P. penetrans* (Cobb) Filipjev & Schuurmans Stekhoven) ranged from 35 to 76% and *Criconemella* ranged from 12 to 54% occurrence on field crops (1).

The geographic patterns of nematodes across large land areas such as states are affected by many factors, but crop plants exert major influences because of their range of suitability as hosts (3,10,12,19). Nonhosts usually cause a relatively rapid decline of certain nematode species (12). Resistant cultivars also have a major negative impact and frequently are associated with shifts in species (6,14,15) or races (16,19,20). Among *Meloidogyne* species, *M. incognita* (Kofoid & White) Chitwood appears to dominate where susceptible tobacco cultivars have been grown, but *M. arenaria* (Neal) Chitwood and/or *M. javanica* (Treub) Chitwood become dominant if *M. incognita*-resistant cultivars are used for long periods (14). *Heterodera glycines* Ichinohe race-specific resistant soybean cultivars have effected shifts to nematode genotypes that are able to damage those cultivars (16,18,19).

Nematode problems generally are more severe in sandy soils, such as those found in the coastal plain, than in finer textured soils (2,5,13,17,18). Nematode spatial patterns (1,11) and damage potentials (2,5,17,18) have been derived from crop responses to nematodes in different soil types.

Management of nematodes can be successful but must be targeted to the species present. Furthermore, research and extension priorities can be better established if nematode incidence is accurately assessed. The objective of this research was to determine the frequencies of occurrence of plant-parasitic nematodes in the coastal plain of North Carolina.

MATERIALS AND METHODS

A systematic nematode survey of the North Carolina coastal plain was conducted between October 1985 and January 1986. Three east-west (E-W) and two north-south (N-S) transects were established. The E-W transects were along the Virginia border through the central counties of North Carolina and roughly parallel to the South Carolina border. The N-S transects were established so that the western one was about 60–70 km east of the coastal plain-piedmont boundary and the other was 125–150 km east of the first N-S transect. Because Sampson County is the largest county in North Carolina and has a wide range of crops but was missed by the five transects, it was sampled separately using one N-S and three E-W transects.

Fields to be sampled were selected by stopping at 1.6-km intervals along each transect, except for lawns or towns. Thirty soil cores 2.5 cm in diameter, taken 20 cm deep, were collected in an X-pattern from about 1 ha at each sample site. The soil samples were transported to the laboratory in insulated ice chests.

After mixing, each field sample was divided into three 500-cm^3 parts: 1) soil for extraction of nematodes, 2) differential host test for *H. glycines* races, and 3) differential host test for *Meloidogyne* species. Nematodes were extracted from soil using a combination of elutriation (4) and centrifugation (9). The other two portions were divided into 100-cm^3 aliquants and placed in 7.5- or 10-cm-diameter clay pots, which were then filled with a steamed soil-sand (1:1) mixture. *Nicotiana tabacum* L. 'NC 95,' *Lycopersicon esculentum* Mill. 'Rutgers,' *Arachis hypogaea* L. 'Florunner,' and *Gossypium hirsutum* L. 'Deltapine 61' were used for the host differential test for detecting species of *Meloidogyne* (10-cm pots) (8). *Glycine max* (L.) Merr. 'Lee 68,' 'Pickett 71,' 'Peking,' PI 90763, and PI 88788 seedlings were used for the host differential test for detecting races of *H. glycines* (7.5-cm pots) (7). Both host differential tests were harvested, and the following data were collected. For *Meloidogyne*, the numbers of juveniles and males in the potted soil, root galls, and females within the root were

Table 1. Crops grown in fields sampled during the 1985–1986 nematode survey in the North Carolina coastal plain

Crop	No. fields	Percentage of total fields sampled
Bermudagrass	5	0.6
Corn	256	32.0
Cotton	18	2.2
Fallow/weeds	41	5.1
Fescue	6	0.8
Miscellaneous	16	2.0
Peanut	60	7.5
Sorghum	12	1.5
Soybean	270	33.8
Sweet potato	11	1.4
Tobacco	85	10.6
Wheat	7	0.9
Vegetables	13	1.6
Total	800	100

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determined. Species and races were determined where numbers were sufficient (8). For *H. glycines*, the soil was gently removed from the roots and the cysts were dislodged from the roots with a high-water-pressure stream. Races (7) were determined for samples in which reproduction was judged sufficient for reliable differentiation.

Means, ranges, and frequencies of occurrence were calculated for each nematode taxon and crop combination across the coastal plain. Similar data were computed for selected counties.

RESULTS

Sample sites were divided into 13 categories based on the crop present (Table 1). Corn and soybean were the most frequently encountered crops (66%) (Table 1). Tobacco, peanut, and fallow (fields without crops but infested with weeds) also represented a significant number of fields sampled in 1985.

Tylenchorhynchus and *Helicotylenchus* plus *Scutellonema* were the most frequently detected genera in this survey (Table 2). Other nematodes with a high incidence were: *Criconemella* spp. (48%), *H. glycines* (25%), *Meloidogyne* (50%), and *Pratylenchus* (58%). The ranges in population densities for nematode taxa varied widely. The most common species within respective genera were *T. claytoni* Steiner, *H. dihystera* (Cobb) Sher, *C. ornata* (Raski) Lúc & Raski, *M. incognita*, *M. hapla* Chitwood, *P. brachyurus*, and *P. zeae*.

Occurrence of migratory ectoparasites, except *Tylenchorhynchus*, was low. *Belonolaimus* (<1%) and *Xiphinema* (19%) are large nematodes and some may have been lost in the extraction process. *Paratrichodorus minor* (Colbran) Siddiqi was recovered from 9% of the samples and in low numbers except in one sample. *Paratylenchus* spp. were rare (<1%).

Meloidogyne spp. detection ranged from 35% of the soybean fields up to 90% of the peanut fields (Table 3). From the 401 fields in which *Meloidogyne* was detected on the Rutgers tomato bioassay, 31% reproduced on NC-95 tobacco (*M. arenaria, M. javanica*, races 2 and 4 of *M. incognita*, and/or *M. hapla*), 17% on peanut (*M. hapla* and race 1 of *M. arenaria*), and 15% on cotton (races 3 and 4 of *M. incognita*) (Table 4). *M. hapla* incidence was high in counties with intensive peanut production (Bertie, Bladen, Edgecombe, Gates, Hertford, Martin, and Northampton). *M. incognita* and *M. arenaria* were more general in their occurrence.

H. glycines was present in 33% of the soybean fields sampled and in 17% from all nonhosts (Table 5). Even though the percent occurrence of juveniles and cysts correlated relatively well ($r = 0.95$), the numbers did not ($r = 0.15–0.28$ depending on whether zeros were removed). The *H. glycines* race (8) frequency distribution (based on 156 bioassays that contained sufficient population densities to determine races) was: 1 = 18%, 2 = 21%, 3 = 15%, 4 = 7%, 5 = 16%, and others = 23%. Three distinct groups, based on reproduction on the differentials, were evident within those classified as others: group A (reproduced on Pickett 71 and Lee 68 only) = 52%, group B (reproduced on Lee 68, Pickett 71, and Peking) = 44%, and group C (reproduced on Lee 68, Pickett 71, PI 88788, and PI 90763) = 4%. *H. glycines* infestation was high in Beaufort, Gates, Harnett, Hoke, Hyde, Lenoir, Pasquotank, Pitt, Robeson, Sampson, Tyrrell, and Washington counties (Table 4).

Of three major pathogenic genera, *Meloidogyne, Heterodera,* and *Pratylenchus*, all were absent in 12.1% of the samples and occurred singly in 19.6, 4.4, and 18.6%, respectively. *Meloidogyne* and *H. glycines*, *Meloidogyne* and *Pratylenchus*, and *H. glycines* and *Pratylenchus* were present in 5.6, 24.8, and 4.9% of the samples, respectively. All three occurred together 10% of the time.

DISCUSSION

Soybean, tobacco, and peanut had major nematode problems that would require implementation of control if the same crops were grown the subsequent year. The management of nematodes on these crops is complicated by the presence of races of *H. glycines* and variable species and races of *Meloidogyne*. It is important to evaluate the host-parasite relationships of *H. glycines, M. incognita, M. arenaria,* and *M. hapla* in greater depth to determine the genetic basis of race and species shifts. In contrast to these three crops, corn has fewer nematode-related problems.

Currently, 33% of the soybean fields in the coastal plain are infested with *H. glycines*. These infested fields are distributed throughout the coastal plain. The first infested field in the United States was confirmed in North Carolina to have *H. glycines* in 1954 (21). Most of the infestations (80%) in 1976 were race 1 (D. P. Schmitt, *unpublished*). In the present study, only 18% were race 1. The shift toward other *H. glycines* phenotypes most likely resulted from heavy reliance

Table 2. Incidence of plant-parasitic nematodes in the North Carolina coastal plain from 800 fields after the 1985 harvest

Nematode genera	Fields infested No.	Fields infested %	Means[a] (no./ 500 cm³ soil)
Belonolaimus	2	<1	60
Criconemella	384	48	305
Helicotylenchus + *Scutellonema*	631	79	584
Hemicycliophora	2	<1	230
Heterodera glycines	198	25	211 (86)[b]
Hoplolaimus	19	2	154[c]
Meloidogyne	370 (401)[d]	46 (50)	330
Paratrichodorus	75	9	38
Paratylenchus	2	<1	185
Pratylenchus	466	58	179
Rotylenchulus reniformis	2	<1	...
Tylenchorhynchus	666	83	343
Xiphinema	151	19	42

[a] Most frequently occurring species within genus: *Criconemella ornata, Helicotylenchus dihystera, Heterodera glycines, Meloidogyne incognita, M. hapla, Paratrichodorus minor, Pratylenchus brachyurus, P. zeae,* and *Tylenchorhynchus claytoni.*

[b] Second-stage juveniles from 112 samples (first number); cysts from 177 samples (second number).

[c] *Hoplolaimus galeatus* + *H. columbus*. It was estimated that one-third of the samples containing *Hoplolaimus* were *H. columbus.*

[d] More (number in parentheses) were recovered in the bioassay than from soil samples.

Table 3. Percent occurrence of *Meloidogyne* spp. after harvest of selected crops in 1985 in the North Carolina coastal plain

Crop	No. fields	Fields infested with *Meloidogyne* spp. No.	Fields infested with *Meloidogyne* spp. %
Tobacco	85	51	60
Soybean	270	94	35
Corn	256	131	51
Cotton	18	15	83
Sorghum	12	9	75
Peanut	60	54	90

Table 4. Spatial patterns of *Meloidogyne* spp. and *Heterodera glycines* by county in the North Carolina coastal plain after the 1985 harvest

		No. infested fields[a]		No. samples with *Meloidogyne* spp. reproducing on			
County	No. samples	*Heterodera glycines*	*Meloidogyne*	Tomato (Rutgers)	Tobacco (NC-95)	Peanut (Florunner)	Cotton (Deltapine 61)
Beaufort	7	4	5	1	0	0	1
Bertie	22	2	13	11	5	4	0
Bladen	34	3	19	18	2	3	3
Brunswick	19	1	5	8	2	1	0
Camden	4	2	1	1	1	1	0
Carteret	5	2	3	1	0	0	0
Columbus	18	2	7	11	2	0	0
Craven	6	0	2	3	0	0	0
Cumberland	14	2	4	5	1	1	1
Currituck	11	4	3	2	1	0	0
Duplin	17	3	13	14	4	1	3
Edgecomb	14	2	11	11	3	3	1
Franklin	13	1	2	2	0	0	0
Gates	30	10	21	19	12	11	0
Granville	18	1	4	4	3	0	0
Greene	7	1	5	4	1	1	1
Halifax	12	0	3	1	0	0	0
Harnett	19	8	6	8	1	0	0
Hertford	21	3	19	18	11	8	0
Hoke	34	9	9	10	4	0	3
Hyde	11	7	4	1	0	0	0
Johnston	42	7	16	18	14	2	0
Jones	6	1	1	0	0	0	0
Lenior	16	6	8	12	1	0	2
Martin	32	5	18	22	9	5	0
Moore	1	0	0	0	0	0	0
Nash	19	0	6	4	3	0	0
Northampton	34	1	26	26	5	8	0
Onslow	11	4	7	8	3	2	1
Pasquotank	5	3	2	2	0	0	0
Pender	31	2	15	23	6	3	5
Person	6	0	0	0	0	0	0
Pitt	28	9	15	14	3	2	1
Robeson	9	4	2	1	0	0	0
Sampson	103	43	54	69	10	4	34
Scotland	14	3	6	6	0	0	0
Tyrrell	15	5	5	5	2	2	0
Vance	11	2	3	5	4	2	0
Wake	8	0	3	4	3	2	1
Warren	31	3	6	10	5	2	0
Washington	19	7	8	7	0	2	0
Wilson	23	5	10	12	2	0	2
Totals	800	177	370	401	123	70	59

[a] Number of infested fields based on extraction from soil; occurrence of *H. glycines* based on detection of cysts.

on race 1-resistant soybean cultivars from the mid-1970s to the present. Such practices should be discouraged, especially since economical rotation options are available.

Meloidogyne species may be slightly less prevalent in North Carolina now than in 1966–1968 (50 vs. 73%) (1). Our last survey through the extension service indicated a 70% incidence on tobacco and associated crops. Some bias might have occurred because many of these early samples collected during the nematode assay pilot project were selected from problem fields. In fact, a 1983 survey through the extension service indicated that this nematode group occurs in >70% of the fields supporting tobacco and associated crops (excluding most fields not cropped but infested with weeds [K. R. Barker, *unpublished*]). Overall, frequencies of occurrence of *Meloidogyne* spp. during the past 20 yr have changed little on tobacco, decreased on corn and soybeans, remained about the same on peanut, and increased on cotton. The slight decline on soybeans and corn may be related to the development and use of cultivars resistant to *M. incognita*. The increase on cotton may be related to the discontinued use of fumigant nematicides.

Researchers and growers need to evaluate present management tactics for *Meloidogyne* spp. The genus is widespread over the coastal plain; as many as 90% of the peanut fields are infested with either *M. hapla* or *M. arenaria*. The occurrence of *M. arenaria* on *M. incognita*-resistant tobacco and soybean cultivars is increasing. In addition, major efforts in research and extension will be required to advance our knowledge of the biology, ecology, and management of these important nematodes.

Population changes of certain nem-

Table 5. Occurrence of *Heterodera glycines* in the North Carolina coastal plain from October 1985 to January 1986[a]

Crop	No. fields	Cyst	J2[b]
Soybean	270	89	71
Nonhosts	530	88	41
Corn	256	54	21
Cotton	18	1	0
Peanut	60	5	1
Sorghum	12	3	1
Tobacco	85	10	5
Others	99	15	13
Total[c]	800	177	112

[a] Correlation coefficient of cyst vs. J2 occurrence = 0.95 (P = 0.001); correlation coefficient for numbers of cysts vs. numbers of J2 for samples with cyst and J2 present = 0.15.

[b] Second-stage juveniles.

[c] *H. glycines* was detected in 198 fields, but only cysts or juveniles were recovered from some fields.

atodes that occurred during the past 15–20 yr may be due in part to changes in cultural practices or may even reflect differences in extraction efficiency. For example, the decline in incidence of *P. minor*, a serious pathogen on corn, could have resulted from the widespread use of nonfumigant insecticide/nematicides. (This nematode had a very high frequency of occurrence 15–20 yr ago [1].) Also, the larger nematodes *Belonolaimus* and *Xiphinema* were more efficiently extracted by sugar flotation than with elutriation-centrifugation.

The nematode communities of the North Carolina coastal plain are dynamic, and some have changed considerably during the past 20 yr. Systematic surveys should be conducted frequently to monitor these changes so research and extension priorities can be adjusted. Effective management of nematodes for certain crops, especially tobacco, peanuts, soybeans, and cotton, is essential if growers are to produce these crops profitably.

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