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Plant-parasitic Nematodes on Soybean in South Carolina

S. A. Lewis,[1] C. E. Drye,[2] J. A. Saunders,[3] E. R. Shipe,[4] and J. M. Halbrendt[5]

Abstract: Fields in a concentrated area of soybean production in South Carolina were chosen for soil sampling to determine the distribution of plant-parasitic nematodes. Five hundred sampling sites were distributed over 19 counties according to county soybean acreage. *Helicotylenchus* and *Scutellonema* were identified most frequently from soil samples; together, these genera occurred in over 70% of the samples. *Pratylenchus* and *Paratrichodorus* were each observed in more than 60% of fields. *Meloidogyne* spp. were found in 27% of the fields and *Hoplolaimus columbus* in 14%. *Rotylenchulus reniformis* and *Belonolaimus* sp. each occurred in less than 10% of the fields. *Tylenchorhynchus* and *Mesocriconema* (*Criconemella*) were each present in over 40% of the fields, but numbers from each field were low. Of the fields sampled, 14% contained *Heterodera glycines*. Of these, 47% were race 14 and 32% were race 3. Races 9, 6, and 10 were also observed.

Key words: Belonolaimus, Criconemella, Glycine max, Helicotylenchus, Heterodera glycines, Hoplolaimus columbus, Meloidogyne, Mesocriconema, nematode, *Paratrichodorus, Pratylenchus,* race, *Rotylenchulus reniformis,* sampling, *Scutellonema,* soybean, survey, threshold, *Tylenchorhynchus.*

Plant-parasitic nematodes can cause significant yield suppression in soybean (*Glycine max*), yet the economics of production often indicate that nematicides will be of little value (8). Soybean cultivar resistance to specific nematodes is available, with newer cultivars having resistance to multiple species of nematodes. For example, Hagood (10) is a high-yielding, multiple-nematode-resistant Group VII cultivar, having resistance to race 3 of *Heterodera glycines,* moderate resistance to *Meloidogyne incognita,* and tolerance to *Hoplolaimus columbus.* Development and effective use of nematode-resistant soybean requires a knowledge base of the important species and races present.

The incidence and predominance of plant-parasitic nematodes in soybean fields in South Carolina is unknown; however, *H. columbus, M. incognita, M. arenaria,* and *H. glycines* occur frequently in many soybean field samples sent to the Clemson University Nematode Assay Laboratory. These species are considered highly aggressive on soybean (9). In addition, *Pratylenchus, Tylenchorhynchus, Mesocriconema* (*Criconemella*), *Helicotylenchus, Paratrichodorus, Scutellonema, Belonolaimus,* and *Rotylenchulus reniformis* are encountered in field samples. Knowledge of the incidence of the major plant-parasitic nematode species is important in determining the best means of deploying resistant cultivars.

The development of the Plant-Nematode Resistance Laboratory at Clemson University has provided a capability to screen thousands of early generation soybean lines each year for resistance to races 3 and 14 of *H. glycines* (4). However, a nematode survey in North Carolina showed that 21% of the *H. glycines* populations were race 2, 7% race 4, 16% race 5, and 23% other *H. glycines* races (8). Adapted soybean cultivars with adequate resistance (i.e., to races 2, 4, and most of the others) were not available. Because cultivar resistance is the primary nematode management tactic, knowledge of races of *H. glycines* within a region and state should influence the choice of populations and races used in the resistance assay of new soybean lines and the emphasis of the local soybean breeding effort.

Our objectives were to determine the incidence of plant-parasitic nematode genera and to determine the races of *H. gly-*

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[1] Professor, Department of Plant Pathology and Physiology, Clemson University, Clemson, SC 29634-0377.
[2] Professor, Department of Plant Pathology and Physiology, Clemson University, Edisto Research and Education Center, P.O. Box 247, Blackville, SC 29817.
[3] Ag Science Associate III, Ag Services Laboratory, Clemson University, Clemson, SC 29634.
[4] Professor, Department of Agronomy and Soils, Clemson University, Clemson, SC 29634.
[5] Former Visiting Assistant Professor, Clemson University. Present address: Pennsylvania State University Fruit Research Laboratory, Biglerville, PA 17307.

cines present in the major soybean growing region of South Carolina.

Materials and Methods

An area of concentrated soybean production was chosen as the sampling location. A total of 499 fields were sampled in 1987 and 500 in 1989 in 19 counties. The number of fields sampled in each county was determined by acreage, with larger numbers of samples concentrated in higher acreage counties. The predetermined number of sampling sites was distributed by dividing each county map into quarters and arbitrarily placing the appropriate number of sites on the map. Samples were taken at the soybean field closest to the marked site. At each selected field, 20 soil cores (2.54-cm-d × 15 cm deep) were taken from the root zone of soybean plants, combined in a plastic bag, and stored in an insulated cooler. A 500 cm^3 aliquant from each field sample was processed, with one-fifth collected on the 38 μm-pore sieve, using a combination of semi-automatic elutriation (1) and centrifugal-flotation, and enumerated. Nematode damage thresholds for South Carolina (2) were used to determine whether densities were greater than threshold levels and, therefore, likely to cause yield loss in soybean.

If samples contained *H. glycines,* the nematodes in the remaining field sample were increased for race determinations on susceptible 'Essex' and 'Lee 74' soybean growing in 20-cm-d plastic pots in the greenhouse. Some populations were numerous enough to permit a race identification test after one generation, some required several generations, and others did not reproduce sufficiently to conduct the race identification. Thirty-nine race determinations were made from the 72 fields containing *H. glycines* in 1987. Thirty-three populations did not provide sufficient inoculum for testing after five generations on Essex or Lee 74 soybean.

A modified version of a greenhouse bioassay (4) was used for race determination, in which cysts were collected from culture plants and ground against a 150-μm-pore (100 mesh) sieve. Eggs and debris were washed through onto a 25-μm-pore (500 mesh) sieve, collected and washed onto a sugar gradient, and centrifuged at 420 *g* for 5 minutes. The egg layer was removed, and the eggs were collected on a 25-μm-pore sieve, washed, and diluted for counting.

Seeds of the four *H. glycines* race differential soybean lines (3) and Lee 74 were germinated in regular weight seed germination paper for 3 days at 24–27 C. Todd planter trays (Speedling Incorporated, Sun City, FL) were filled with sand, and 1,500–2,000 eggs of each *H. glycines* population were pipetted into individual chambers. Five seedlings per population were transplanted to the infested chambers after 3 days, grown for 35 days, and harvested and assayed for females of *H. glycines* (4). Confidence intervals were calculated for *H. glycines* race indices (6,11).

Results

Helicotylenchus and *Scutellonema,* the most frequently observed plant-parasitic nematodes, were found in at least 70% of the samples (Table 1). Together, their densities were high enough to cause plant damage in 10% of the samples in which they occurred. The average number was more than 200/100 cm^3 soil each year. *Pratylenchus* spp. and *Paratrichodorus* (*Trichodorus*) *spp.* were each encountered in more than 60% of the fields. The incidences of *H. glycines* and *Meloidogyne* spp. were approximately 14 and 27%, respectively. The incidences of *Rotylenchulus reniformis* and *Belonolaimus* sp. were very low (<10%); however, the average numbers of *R. reniformis* recovered per field were very high compared with those of other species. *Tylenchorhynchus* sp. and *Mesocriconema* (*Criconemella*) spp. were present in nearly one-half of the fields, but numbers were generally far below damage thresholds.

Meloidogyne, Pratylenchus, and *Heterodera* were present together in 4% of the fields. *Meloidogyne* and *Pratylenchus, Meloidogyne* and *Heterodera,* and *Pratylenchus* and *He-*

TABLE 1. Number and percentage of fields infested with nematode genera and percentage of samples exceeding the damage threshold.

Nematode	Number of fields infested†		Percentage of fields infested		Fields with nematodes over damage threshold (%)‡	
	1987	1989	1987	1989	1987	1989
Hoplolaimus columbus	64	69	13	14	44	41
Heterodera glycines	70	84	14	17	100	100
Xiphinema sp.	44	23	9	5	2	0
Pratylenchus spp.	313	348	63	70	12	13
Rotylenchulus reniformis	3	1	1	1	75	66
Mesocriconema spp.	218	231	44	46	4	3
Meloidogyne spp.	134	141	27	28	56	28
Helicotylenchus and *Scutellenema*	347	406	70	81	10	11
Belonolaimus longicaudatus	14	39	3	8	100	100
Paratrichodorus (*Trichodorus*) spp.	327	304	66	61	13	23
Tylenchorhynchus spp.	236	209	47	42	0	1

Total number of fields sampled in 1987 and 1989 were 499 and 500, respectively.
† The most common species occurring within each genus were *Pratylenchus brachyurus, P. scribneri, Mesocriconema curvata, Helicotylenchus dihystera, Scutellonema brachyurum, Paratrichodorus minor, Tylenchorhynchus claytoni, Meloidogyne incognita,* and *M. arenaria.*
‡ The percentage of fields with a particular genus over damage threshold levels, of those fields having that genus.

terodera occurred together in 18, 4, and 8% of the samples, respectively. Values were similar in the 1989 survey, except that *Pratylenchus* and *Heterodera* occurred in 12% of the samples. None of the three genera were present in 25% of the samples.

Meloidogyne spp. and *H. columbus* and *H. glycines* and *H. columbus* occurred together in 3 and 1% of the samples, respectively.

Thirty-nine race determinations of *H. glycines* were made from populations collected from the 72 infested fields in 1987 (Table 2). Seventeen (43%) of these populations were race 14, 11 (28%) were race 3, 5 (13%) were race 9, 2 (5%) were race 6, 2 (5%) were race 10, and 2 (5%) were designated race 9/14 because different results were obtained in two tests. Seventy-one percent of fields with *H. glycines* had either race 3 or 14.

DISCUSSION

H. columbus, H. glycines, R. reniformis, Meloidogyne spp., and *Belonolaimus* sp. were frequently present in numbers sufficient to suppress soybean yield. *Pratylenchus* spp. may be more important than the relatively low mean soil densities would indicate. They were present in more than 60% of fields, and assay of root densities would have given a more definite indication of their damage potential. Previous observations (Lewis, unpubl.) indicated that *Pratylenchus* populations in roots increased slowly until early pod-fill, when densities increased rapidly. An impact on yield is possible (5). *Meloidogyne* might have been found in a higher percentage of samples if a bioassay had been used.

The most recent race characterization scheme (7) for *H. glycines* includes the 16 races possible with four host differential soybean lines (3). The predominance of races 3 and 14, which together composed 79% of the cyst nematode populations, indicates that the emphasis of the local soybean screening program is correctly directed toward screening primarily against these races. Populations of races 1, 2, or 4 were not encountered, although they make up a significant number of populations in North Carolina. Race 3 was found in 32% of our samples but was found in only 15% of North Carolina fields (8). A smaller percentage of fields in South Carolina (14.4%) was infested with *H. glycines* than in North Carolina, where 25% of soybean fields were infested after the 1985

TABLE 2. Mean female indices, followed by 95% confidence limits, on soybean genotypes used for race characterization of *Heterodera glycines* populations from 40 soybean fields in South Carolina.

	Percentage of Lee				
Sample	88788	Pickett	Peking	90763	Race
9	2.5 ± 1.1	45.2 ± 9.9	38.9 ± 10.3	13.1 ± 5.1	14
24	3.0 ± 3.0	110.4 ± 44.0	61.2 ± 18.5	38.6 ± 9.1	14
51	4.1 ± 3.0	61.0 ± 21.2	6.8 ± 4.3	5.4 ± 4.3	6
54	4.8 ± 4.8	147.6 ± 37.0	23.8 ± 4.2	38.1 ± 13.8	14
68	1.0 ± 1.1	86.5 ± 22.8	67.7 ± 17.9	13.8 ± 4.5	14
69	1.9 ± 1.9	56.1 ± 18.9	47.0 ± 13.6	18.2 ± 7.5	14
76	2.0 ± 1.3	45.2 ± 13.7	7.1 ± 5.0	6.1 ± 2.6	6
102	0.7 ± 0.8	0.7 ± 0.8	0.7 ± 0.8	1.5 ± 1.5	3
103	0.0	96.9 ± 40.7	15.0 ± 10.8	15.6 ± 5.3	14
114	3.4 ± 2.4	87.5 ± 20.3	31.4 ± 9.0	24.7 ± 8.2	14
117	2.9 ± 1.9	0.0	4.3 ± 3.1	0.0	3
124	0.0	2.1 ± 1.4	1.0 ± 1.1	2.1 ± 1.4	3
131	0.0	0.0	0.0	0.0	3
138	0.0	30.4 ± 25.6	21.7 ± 7.3	13.0 ± 5.5	14
163	2.5 ± 2.5	100.0 ± 34.5	25.0 ± 5.8	15.0 ± 9.5	14
174	2.3 ± 2.4	88.4 ± 30.3	65.1 ± 22.5	7.0 ± 5.2	9
176	9.4 ± 4.5	168.8 ± 46.2	56.3 ± 18.5	31.3 ± 13.2	14
177	1.2 ± 1.3	97.0 ± 39.6	77.0 ± 28.2	17.9 ± 9.8	14
214	0.0	6.5 ± 3.8	2.4 ± 1.1	0.8 ± 0.8	3
220	2.3 ± 2.4	0.0	3.8 ± 4.0	0.0	3
221	0.0	21.4 ± 10.2	60.0 ± 19.6	25.0 ± 11.3	14
250	3.4 ± 2.5	70.3 ± 27.3	44.6 ± 15.3	27.5 ± 12.2	14
263	0.0	23.1 ± 10.7	23.1 ± 11.5	2.6 ± 2.7	9
265	4.3 ± 4.6	73.9 ± 35.2	43.5 ± 18.6	8.7 ± 9.1	9
272	2.9 ± 1.4	97.8 ± 21.4	24.5 ± 5.7	18.6 ± 4.0	14
273	0.5 ± 0.5	81.1 ± 19.3	38.6 ± 11.5	25.8 ± 7.5	14
358	0.0	1.8 ± 1.9	0.0	0.0	3
383	0.0	73.2 ± 18.2	9.8 ± 5.0	13.4 ± 4.1	10
384	2.1 ± 1.4	3.1 ± 1.5	0.0	0.0	3
411	1.2 ± 1.2	58.3 ± 12.8	72.2 ± 14.6	9.7 ± 4.0	9
416	0.7 ± 0.7	58.1 ± 17.9	41.7 ± 12.9	51.4 ± 18.7	14
417	0.5 ± 0.5	89.9 ± 22.9	39.5 ± 11.3	14.7 ± 4.4	14
418	2.2 ± 1.1	77.6 ± 23.1	54.0 ± 19.6	25.0 ± 6.1	14
437	0.0	112.4 ± 57.0	47.6 ± 17.9	0.0	9
447	0.0	2.7 ± 1.8	0.0	0.0	3
448	0.0	61.9 ± 20.2	22.9 ± 10.2	30.7 ± 11.4	14
468	1.4 ± 1.4	43.8 ± 11.3	12.3 ± 4.9	17.8 ± 5.4	14
475	0.0	0.7 ± 0.7	0.0	0.0	3
487	0.0	0.0	0.0	0.0	3

harvest and 33% were infested 2 years later (8). This difference may be due to the later occurrence of the first known infestation of *H. glycines* in South Carolina (1973 compared with 1954 in North Carolina), the geographical distance of the sampling area from the original site of infestation, a shorter history of soybean production in an area where cotton production is traditional, and the recent grower practice of removing nematode-problem soybean fields from production.

Phytoparasitic nematodes are a major yield-limiting pest of soybean in the United States. Management strategies for plant-parasitic nematodes on soybean are limited. Wide host ranges of *M. incognita, M. arenaria,* and *H. columbus* limit rotation options. Nematicides can effectively alleviate yield losses; however, the low unit value of soybean makes efficacious chemical application rates uneconomical. Use of resistant cultivars is effective if correctly matched to species and races present in a particular field site. Currently available soybean cultivars have resistance or tolerance to the two common *Meloidogyne* species and to the races of *H. glycines* found in the state. However, monitoring for *H. glycines* races for which there is no adapted resistance should continue.

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