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Nematodes in Michigan I. Distribution of *Heterodera glycines* and Other Plant-parasitic Nematodes in Soybean

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Abstract: In 1992, a detection survey for *Heterodera glycines* (soybean cyst nematode) was conducted in 16 counties in Michigan. The nematode was detected in 12 counties, with absolute frequencies ranging from 6 to 100%. A total of 149 samples was collected, and 53% were infested with *H. glycines.* Eighty-four growers participated in the survey, and 38 had samples collected from more than one field. Of the 38 growers, 42% had all samples positive for *H. glycines,* 18% had some positive and negative fields, and 39% had all negative. A risk index was developed to quantify three types of risks: short-term, long-term, and border risk from neighboring counties. Soybean yield was regressed on *H. glycines* population density and number of years of soybean. Thirty-one percent of the variability in soybean yields was explained by *H. glycines* cyst population densities. Total number of years in soybean over the last 20 year period explained 19% of the variability in yields. In addition, *H. glycines* frequencies and population densities were inversely related to *Pratylenchus* spp. frequencies and population densities.

Key words: community ecology, distribution, *Heterodera glycines, Glycine max,* Michigan, nematode, *Pratylenchus* spp., risk assessment, soybean, soybean cyst nematode.

Soybean cyst nematode *(Heterodera glycines)* is a major pest of soybean *(Glycine max)* in the north central United States. Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, and Wisconsin have all reported *H. glycines* infestations (8). This nematode was the major limiting factor in soybean production in the north central region of the United States from 1989–1991 (5).

Michigan ranked 18th in U.S. soybean production in 1981. Growers in Michigan planted 566,000 hectares (ca. 1,400,000 acres) of soybean in 1991 and produced 1,188,000 Mg (52,800,000 bu) (1). The state moved into the top 10 soybean producers in the United States in 1991, accounting for 2.7% of the nation's soybean production. Soybean acreage has steadily increased within the state as 396,761 hectares (980,000 acres) were planted in 1981 and production was 674,750 Mg (29,100,000 bu) (2). This upward trend in soybean production has presumably increased risk of *H. glycines* problems developing within the state.

The first detection of *H. glycines* in Michigan was in 1987 in Gratiot County (3). Between 1988 and 1991, *H. glycines* was detected in four additional counties (Bay, Berrien, Saginaw, and Van Buren). Most of the detections were in soybean fields; however, one dry edible bean *(Phaseolus vulgaris)* field in Saginaw County was heavily infested. Michigan typically ranks first or second in the United States in dry edible bean production. In 1981, Michigan accounted for approximately 22% of the nation's dry edible bean production (327,182 Mg) and ranked first. Michigan was ranked second in 1991 but still produced 19% of the U.S. crop (282,273 Mg). *Heterodera glycines* therefore poses serious risks to two major agricultural crops, soybean and dry bean, in Michigan. The primary objective of this project was to determine the distribution of *H. glycines* in Michigan. A secondary objective was to better quantify the plant-parasitic nematode community in soybean fields.

Materials and Methods

A detection survey for *Heterodera glycines* was conducted between August and Octo-

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ber 1992 with the assistance of the Michigan State University Cooperative Extension Service. County extension agents were responsible for recruiting soybean growers. Sixteen counties were surveyed (Table 1). A total of 149 soil samples was collected, representing approximately 0.9% of the hectares planted to soybean in the 16 counties surveyed, or a total of 2,259 hectares sampled. Fields were selected based on cropping histories or symptoms observed by the growers or county agents during the 1992 or previous growing seasons. The survey was further biased because samples were collected from the margins of areas expressing symptoms similar to those caused by *H. glycines.* If no symptoms were observed, soil and root samples were collected arbitrarily throughout the site (4).

One bulk soil sample, regardless of field size, was collected per field by a two-member sampling team. Approximately 8–10 root systems and rhizosphere soil composed each sample. Samples were stored at 5 C until processed. All the plant-parasitic nematodes were extracted from the soil with a modified centrifugal flotation procedure with nested sieves with 710-μm and 37-μm openings (6). Nematodes were identified to genus and counted under a stereoscopic microscope at ×40 magnification. When necessary, observations for species identifications were made with a phase contrast microscope at ×1,000. Cyst nematodes were identified based on vulval cone morphologies and morphometrics of the second-stage juveniles (7).

Three statistics were developed to estimate risk associated with *H. glycines* within Michigan. These statistics were modified from Norton (10); however, Norton compared multiple species of nematodes over similar farming practices. In our investigation, procedures were used to compare one species of nematode over several regions in an effort to compare risk assessment among regions. The probability of a field becoming infested with *H. glycines* often depends on the frequency and population densities of *H. glycines* infestations in the county. Density is considered more important in the short term, whereas fre-

TABLE 1. Frequency, density, and risk measurements associated with *Heterodera glycines* in 16 Michigan counties.

County	Frequency† (%)	Number of cysts/100 cm^3 soil	Short-term risk‡	Long-term risk§	Border risk‖
Bay	100	127.5	30.43	25.97	5.46
Berrien	100	16.0	3.82	9.20	1.92
Cass	50	5.5	0.93	2.70	3.69
Clinton	11	28.2	2.23	1.34	11.21
Eaton	0	0.0	0.00	0.00	0.63
Gratiot	100	65.0	15.51	18.54	5.75
Ingham	0	0.0	0.00	0.00	2.21
Lenawee	0	0.0	0.00	0.00	15.25
Midland	6	0.5	0.03	0.09	29.30
Monroe	74	91.8	18.85	16.31	0.00
Saginaw	76	99.5	20.70	17.44	8.06
Sanilac	0	0.0	0.00	0.00	0.00
Shiawassee	44	32.3	5.11	5.75	6.98
St. Joseph	33	2.7	0.37	1.24	1.92
Tuscola	0	0.0	0.00	0.00	13.53
Van Buren	12	23.9	2.02	1.41	4.09

† Frequency = (number of samples containing *H. glycines*)/(number of samples collected) × 100.
‡ Short-term risk = square root (frequency) × density, normalized on a scale from 0 to 100.
§ Long-term risk = square root (density) × frequency, normalized on a scale from 0 to 100.
‖ Border risk = the sum of the long term risk associated with bordering counties divided by the number of associated counties, normalized on a scale from 0 to 100.

quency is more important in the long term. If no positive finds were identified in the county, both short-term and long-term within-county risks are zero. If that assumption is correct, then the most immediate source of infestation is from neighboring counties, and this statistic is identified as border risk. Border risk is the averages of the long-term risks from each of the bordering counties that are infested with *H. glycines,* normalized from 0 to 100.

In addition to the risks of infestation from outside the farm, it is important to assess within-farm risk. For example, in this survey, 21 (25%) of the growers that participated had two soybean fields sampled during the 1992 growing season (Table 2). Three possible states of infestation were identified: neither field infested, one field infested, or two fields infested.

Growers from Saginaw and Midland Counties were later requested to provide 1992 soybean yield data for fields (n = 24) sampled during the year. The growers were also asked how many years in the last 20 soybean was planted in the sampled fields.

RESULTS

Heterodera glycines was found in 53% of the samples collected. Fields in 11 of the 16 counties surveyed were infested with *H. glycines,* with frequencies ranging from 6 to 100%. *Heterodera glycines* infestations were located in the southeast, east central, and southwest soybean production regions of Michigan (Fig. 1). Absolute densities ranged from 1 to 128 *H. glycines* cysts per 100 cm^3 soil (Table 1). These 11 counties constitute ca. 47% of the Michigan farmland planted to soybean annually.

TABLE 2. Number of fields from which *Heterodera glycines* was identified on farms that submitted samples from more than one field.

No. of growers	No. of fields sampled	Fields infested with *H. glycines*	Percentage in each category
46	1	0	54
		1	46
21	2	0	43
		1	14
		2	43
11	3	0	18
		1	18
		2	36
		3	27
4	4	0	75
		1	0
		2	25
		3	0
		4	0
1	5	0	100
1	7	7	100

For the 11 counties that had fields infested with *H. glycines,* the greatest short-term risk was in Bay County, which had the highest average density of 128 *H. glycines* cysts/100 cm^3 soil (Table 1). Bay County also had the highest long-term risk, because of the high frequency (100%) (Table 1). Of the counties in which *H. glycines* was not found, Lenawee County was predicted to have the highest risk of *H. glycines* infestation according to the border statistic (Table 1). Lenawee County ranked second among Michigan counties in soybean production in 1991.

Of the 21 growers who submitted two samples, neither field was infested for 43% of the growers, 14% had one infested field, and 43% had two infested fields (Table 2). Cyst population densities explained 31.1% of the variability in soybean yields (Fig. 2). The number of years of soybean production explained 19% of the variability in soybean yields (Fig. 3). These relationships were based only on yields and cyst densities or number of years in soybeans; farming practices and cultivar differences were not considered.

Eight other genera of plant-parasitic nematodes were recovered from Michigan soybean fields: *Pratylenchus; Meloidogyne; Hoplolaimus; Xiphinema; Paratylenchus; Helicotylenchus; Tylenchorhynchus* and *Criconemella;* and the distributions of these other nematodes varied among regions (Table 3). The southeast region of Michigan had the highest prominence value for *H. glycines.* A high prominence value for *H. glycines* was accompanied by a low prominence value for *Pratylenchus* spp. The northeastern region had a moderate prominence value for *H. glycines,* and a

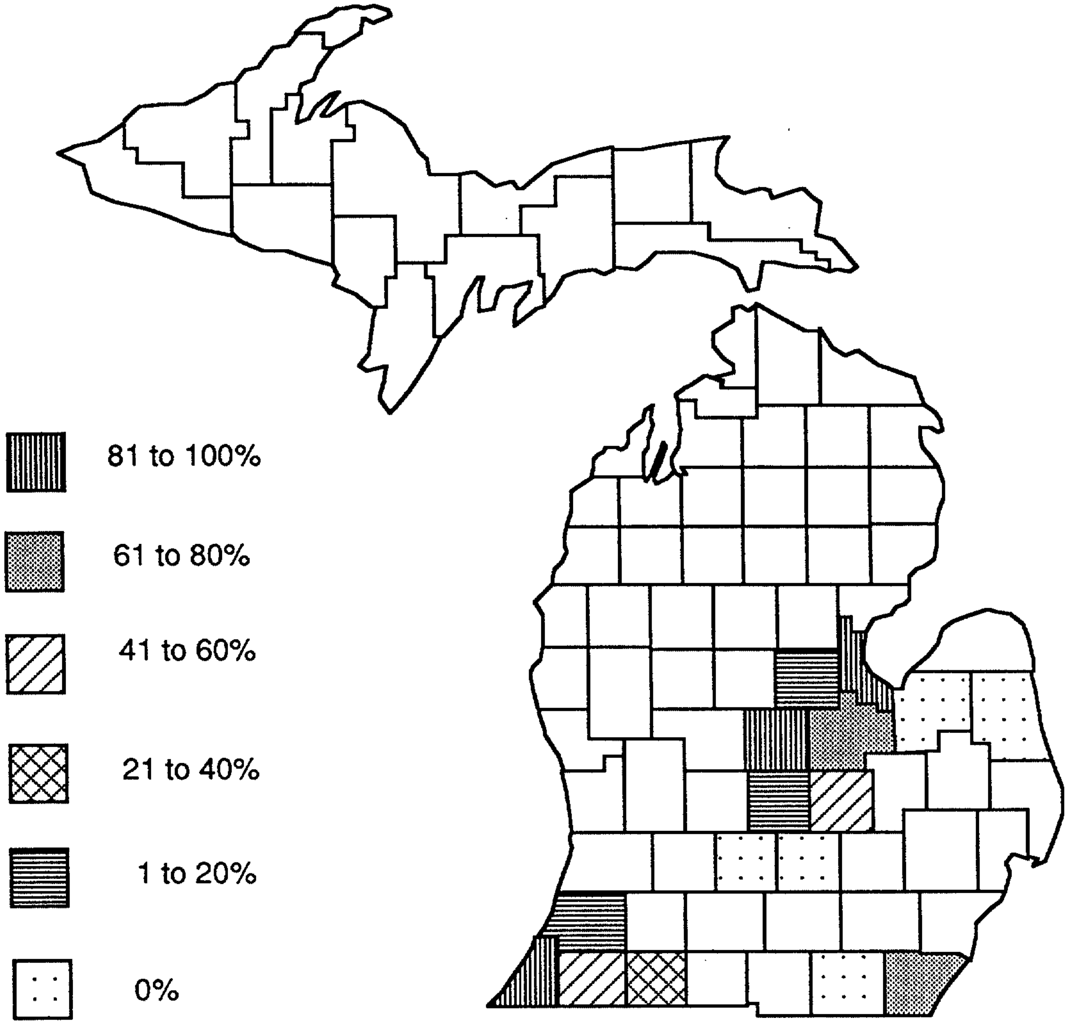

FIG. 1. Distribution of *Heterodera glycines* (soybean cyst nematode) detected in a 1992 survey in Michigan. Percentages refer to percentages of fields sampled that were infected with *H. glycines*.

lower one for *Pratylenchus* spp. In contrast, in the southwest region, the prominence of *H. glycines* was the lowest of all regions, whereas *Pratylenchus* spp. had a very high prominence value (Table 3). In addition, when *H. glycines* values were high, ectoparasites such as *Helicotylenchus* and *Paratylenchus* were prominent.

DISCUSSION

Heterodera glycines has been positively identified in 11 Michigan counties. Of the six leading soybean production counties in Michigan (Saginaw, Lenawee, Shiawassee, Monroe, Gratiot, and Clinton, respectively), only Lenawee County has not had a confirmed *H. glycines* detection. These six counties accounted for approximately 40% of 1991 Michigan soybean production. It is probable that *H. glycines* also exists in Lenawee County; the county has a high border risk index and has not been intensively sampled. In fact, *H. glycines* was later detected in Lenawee County in a 1993 survey. In addition, only two counties (Montcalm and Van Buren) with known infestations of *H. glycines* do not rank in the top 23 in state soybean production. Therefore, it is apparent that *H. glycines* is already having an economic impact on soybean production in Michigan.

The risk statistic was developed to pre-

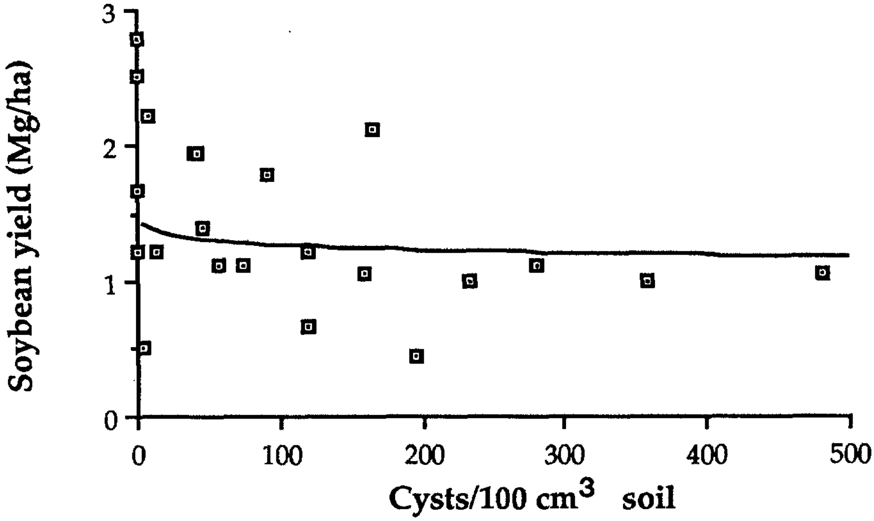

FIG. 2. Relationship between soybean yield and *Heterodera glycines* population density in a 1992 survey in Michigan: $y = 1.488 - 0.11573 \times \log(x)$, $R^2 = 0.311$, where y = soybean yield (Mg/ha) and x = number of cysts per 100 cm^3 soil.

dict the spread of soybean cyst nematode. The basic assumption is that risk of *H. glycines* infestation comes from a variety of sources and is temporal in nature. Risk addresses the following questions: i) what is the probability of having *H. glycines* present in a field, given that *H. glycines* was present in the county; ii) what is the probability of having *H. glycines* present in a county in which *H. glycines* was not present the year before; and iii) what is the probability of having *H. glycines* present in another field on that farm? According to this risk statistic, Midland, Lenawee, Tuscola, and Clinton Counties were at the highest risk of soybean cyst nematode infestations. Soybean cyst nematode had already been detected from Midland and Clinton Coun-

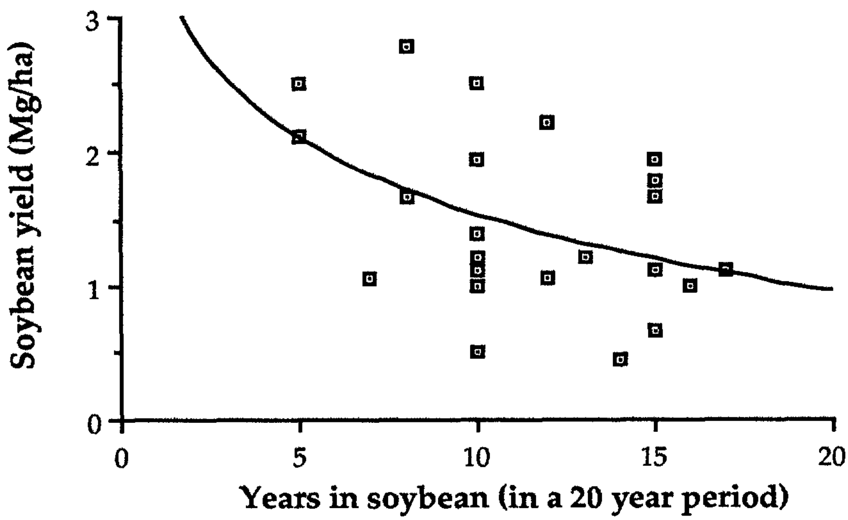

FIG. 3. Relationship between soybean yield and number of years of soybean production (1973–1992) in a 1992 survey in Michigan: $y = 3.4421 - 1.9106 \times \log(x)$, $R^2 = 0.192$, where y = soybean yield (Mg/ha) and x = number of years in soybean in the last 20 years of production.

TABLE 3. Distributions of plant-parasitic nematodes in three *Heterodera glycines*-infested regions in Michigan.

Species	Absolute frequency†	Relative frequency‡	Absolute density§	Relative density‖	Prominence value¶	Relative prominence#
			East Central			
Heterodera glycines	48	16	55.0	23	381	22
Pratylenchus spp.	55	18	16.0	7	119	7
Meloidogyne hapla	2	1	0.6	<1	1	<1
Hoplolaimus galeatus	8	3	1.3	1	4	<1
Xiphinema americanum	3	1	0.4	<1	1	<1
Paratylenchus sp.	58	20	88.1	37	671	38
Helicotylenchus sp.	66	22	57.8	24	470	27
Tylenchorhynchus sp.	53	18	16.5	7	120	7
Criconemella sp.	4	1	1.9	1	4	<1
			Southwest			
Heterodera glycines	22	7	19.0	14	89	8
Pratylenchus spp.	91	29	79.0	57	754	69
Meloidogyne hapla	14	5	0.4	<1	2	<1
Hoplolaimus galeatus	36	11	4.9	4	29	3
Xiphinema americanum	55	18	16.2	12	120	11
Paratylenchus sp.	23	7	4.3	3	21	2
Helicotylenchus sp.	36	11	1.9	1	11	1
Tylenchorhynchus sp.	27	9	10.5	8	55	5
Criconemella sp.	9	3	1.7	1	5	1
			Southeast			
Heterodera glycines	70	23	87.3	38	730	37
Pratylenchus spp.	50	17	6.4	3	45	2
Meloidogyne hapla	0	0	0.0	0	0	0
Hoplolaimus galeatus	0	0	0.0	0	0	0
Xiphinema americanum	10	3	0.6	<1	2	<1
Paratylenchus sp.	40	13	6.5	3	41	2
Helicotylenchus sp.	80	27	123.0	53	1100	55
Tylenchorhynchus sp.	50	17	9.3	4	66	3
Criconemella sp.	0	0	0.0	0	0	0

† Absolute frequency = (number of samples containing a genus or species)/(number of samples collected) × 100 (percent).
‡ Relative frequency = (frequency of genus or species)/(sum of frequency of all genera or species) × 100 (percent).
§ Absolute density = A counted number of individuals per genus or species per fixed area (i.e., number of nematodes per 100 cm^3 soil).
‖ Relative density = (number of individuals of a genus or species in a sample)/total number of all individuals in the sample.
¶ Prominence value = absolute density × square root (absolute frequency).
# Relative prominence = prominence value/sum of all prominence values in sample × 100.

ties, and was identified from Lenawee and Tuscola Counties in a 1993 survey. Therefore, the border risk statistic was a good predictor of soybean cyst nematode spread.

An important management strategy is to identify and isolate infested fields from those that are infested or have infestations below detectable levels. This strategy is important for Michigan soybean producers, because some growers in our survey farmed both soybean cyst nematode-infested and uninfested fields, and it is to their advantage to minimize or prevent the spread of *H. glycines* on their farms.

Preliminary evidence suggests that the presence of *H. glycines* affects the frequencies and densities of other plant-parasitic nematodes in Michigan soybean fields and that *H. glycines* may cause declines in *Pratylenchus* spp. population densities. This phenomenon has been reported previously (9). However, root-lesion nematodes may deserve more attention because they were often recovered from fields with disease symptoms in the absence of *H. glycines*.

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