Journal of Nematology 20(3):417–420. 1988.

Variability in Host Preference Among Field Populations of *Heterodera glycines*[1]

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Abstract: Eighteen soybean fields, six each with race 3, race 4, or Bedford population of *Heterodera glycines,* were selected for testing of host variability. Each field was divided into three sections, and a bulk soil sample was taken from each section. The 54 bulk soil populations (BSP) and 270 single cyst populations (SCP) were subjected to race determination tests. Tests of the 18 BSP and 90 SCP from the race 3 fields revealed that race 3 was the predominant race; however, 68 of the populations tested were other races. Tests of the 18 BSP and 90 SCP from race 4 fields demonstrated that races 2 and 4 were predominant, with 38 and 39 populations, respectively. Tests of the 18 BSP and 90 SCP from the Bedford population fields revealed tremendous variability. Races 2, 4, and 6 were the predominant races, with 32, 31, and 28 populations, respectively. These results indicate that of the three races studied, the Bedford population is the most variable, race 3 shows considerable variability, and race 4 shows very little.

Key words: *Glycine max, Heterodera glycines,* soybean, soybean cyst nematode, variability.

The soybean cyst nematode, *Heterodera glycines* Ichinohe, a serious pathogen on soybeans, has shown a great ability to adapt to resistant soybean cultivars. A race scheme was established to accommodate this variability (2). Four races were described originally (2) and one race has been added (4), but the scheme was designed to accomodate 16 races and numerous other races have been detected (8–10,12).

Luedders (5) reported that variability in *H. glycines* is due to selection, mutation, and migration. Although research involving mutations or migrations of *H. glycines* is lacking, the probability that these two factors cause the high degree of variability observed in *H. glycines* is remote. Selection appears to be the primary vehicle leading to this high degree of variability. By planting resistant soybean cultivars in soil infested with *H. glycines,* new virulent populations of the nematode have developed through selection (6,7,17,18). The maturation of races of *H. glycines* on Bedford is primarily due to selection. Bedford was released in 1978, and populations (races) of *H. glycines* maturing on Bedford were reported from isolated areas in 1982 (unpubl.). This suggests a rapid shift in virulence within field populations of *H. glycines.* This genetic variation in the field makes control of *H. glycines* very difficult.

Genetic variability is also increased in *H. glycines* by sexual reproduction as well as by a multigenic system and sexual promiscuity (multiple mating). Green et al. (3), while working with *Globodera rostochiensis,* discovered that multiple matings occurred and that following the genetics after multiple matings is very difficult, if not impossible. Intermating between races of *H. glycines* has been shown to occur in the greenhouse (11) and probably occurs in the field. The resulting progeny could be similar to the parental races or completely different due to transgressive segregation.

The purpose of this study was to determine the extent of the variability in virulence within fields infested with populations of *H. glycines* that had previously been identified as race 3, race 4, or a population (BP) that reproduced on Bedford soybean.

MATERIALS AND METHODS

Eighteen fields were selected for this study, six each with populations previously identified as soybean cyst nematode (SCN) race 3 (R3), race 4 (R4), or population BP. Each field was divided into three sections, and a bulk soil sample of approximately 2

Received for publication 10 April 1986.
[1] This research was supported primarily by the Science and Education Administration of the U.S. Department of Agriculture under grant from the Competitive Research Grant Office.
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TABLE 1. Reaction† of observed races of *Heterodera glycines* on the standard soybean host differentials.

Race	Differential			
	Pickett	Peking	PI 88788	PI 90763
1	−	−	+	−
2	+	+	+	−
3	−	−	−	−
4	+	+	+	+
5	+	−	+	−
6	+	−	−	−
9	+	+	−	−
15	+	−	+	+

According to Golden et al. (2), Inagaki (4), and Riggs and Schmitt (13).
− = less than 10%, + = 10% or more of the number of females on Lee soybean.

TABLE 2. Bulk soil populations (BSP) and single cyst populations (SCP) of *Heterodera glycines* from race 3, race 4, and Bedford population fields that fit in each race found.

Race	Populations in each race (no.)					
	Race 3 fields		Race 4 fields		Bedford population fields	
	BSP	SCP	BSP	SCP	BSP	SCP
1	0	1	0	0	0	0
2	2	19	4	34	4	28
3	10	30	0	2	0	1
4	2	15	10	29	5	26
5	0	6	0	1	5	5
6	4	16	3	18	4	24
9	0	3	1	6	0	6
15	0	1	0	0	0	0

liters was taken from the center of each. The sample from each section was placed in a 15-cm-d clay pot and two Lee cultivar soybean plants were transplanted into it. Lee was assumed to be susceptible to all known races of *H. glycines* (2). The nematode populations were maintained for 30–60 days to allow the SCN population to increase. The resulting population was termed the bulk soil population (BSP).

Single cyst populations (SCP) were established by selecting 10 cysts from each BSP. Each of the 10 cysts was broken to enhance egg hatch and subsequent root infection by second-stage juveniles (J2). Each broken cyst was placed near the roots of a Lee soybean plant (first true leaf stage) growing in sterilized fine river sand in a 7.5-cm-d pot and maintained for a minimum of 60 days.

The BSP and SCP were subjected to a standard race determination test using the cultivars Pickett and Peking and Plant Introductions (PI) 88788 and 90763. Bedford soybean cultivar was also used to evaluate its possible utilization in race separation. Lee, not classified as a differential, was used as the control. The differentials were inoculated with 4,000 eggs and J2 of *H. glycines* per 7.5-cm-d pot with a repeating syringe. Each differential and the control were replicated three times.

The mature female index (MFI) (12) was used to determine the race as proposed by Golden et al. (2). The Bedford population could be any of the five reported races (2,4) or any undescribed race able to mature on Bedford. Race 1 has been reported to reproduce on Bedford (15), and individual populations of other races also have been shown to reproduce on Bedford (Riggs, unpubl.).

RESULTS

The populations could be divided into eight races based on their reactions on the race differentials (Table 1). From the 18 BSP from R3 fields, 56% were R3 (Table 2). The SCP were more evenly divided but R3 was still predominant with 34% while there were 21% R2, 17% R4, and 18% R6 (Table 2). One of the SCP was R15, the only one found in the study. The average female counts on Lee ranged from 122 to 483.

The BSP from the R4 fields were in four races and the SCP were in six races (Table 2). Among the 18 BSP, 56% were R4. Of the 90 SCP, 38% were R2, 32% R4, and 20% R6; only two SCP were R3 (Table 2). The average female counts on Lee ranged from 104 to 584. All MFI on Pickett were quite high except with the R3 populations where MFI were low on all differentials. Race 4 MFI were well above 10 on all differentials. Bedford was resistant to BSP R2 and R4 populations but susceptible to SCP

TABLE 3. Bulk soil populations (BSP) and single cyst populations (SCP) of *Heterodera glycines* producing females on Bedford soybean relative to the total number of populations of a given race from each field source.

	BSP positive on Bedford : total BSP			SCP positive on Bedford : total BSP			
Race	Race 3 fields	Race 4 fields	BP fields	Race 3 fields	Race 4 fields	BP fields	Total
1	0:0	0:0	0:0	0:0	0:0	0:0	0:0
2	1:2	1:4	4:4	6:19	8:34	22:28	42:91
3	0:10	0:0	0:0	5:30	0:2	1:1	6:43
4	2:2	2:10	1:5	6:15	8:29	16:26	35:87
5	0:0	0:0	5:5	1:6	1:1	4:5	11:17
6	0:4	3:3	4:4	5:16	5:18	16:24	33:69
9	0:0	0:1	0:0	2:3	4:6	6:6	12:16
15	0:0	0:0	0:0	0:1	0:0	0:0	0:1
Total	3:18	6:18	14:18	25:90	26:90	65:90	

R2 and R4 populations. The BSP R6 populations reproduced on Bedford whereas the SCP R6 did not (Table 3).

The 18 BSP from BP fields were about equally divided between R2, R4, R5, and R6 (Table 2). The 90 SCP were in six races with 31% R2, 29% R4, and 27% R6; only one was R3 (Table 2). Average female counts on Lee ranged from 434 to 770. MFI on Pickett ranged from 57 to 103 except for the race 3 populations which had very low MFI on all differentials. The MFI on Bedford were generally above 10 except for four of the five BSP that were R4.

In the whole test, the MFI on PI 90763 were negatively correlated with the counts on Lee ($P \leq 0.05$). MFI on Peking were correlated with MFI on PI 88788 and PI 90763, and MFI on PI 88788 were correlated with MFI on PI 90763 ($P \leq 0.01$). MFI on Bedford were not correlated with counts on Lee nor with MFI on any differential.

Among BSP, 17% from R3 fields, 33% from R4, and 78% from BP fields had MFI above 10 on Bedford (Table 3). Among SCP, 19% from R3, 29% from R4, and 72% from BP fields had MFI above 10 on Bedford. Only one of 42 R3 populations had MFI above 10 on Bedford.

DISCUSSION

The objective of this study was to determine the range of variability within soybean fields infested with *H. glycines*. The variability is amply demonstrated in that in none of the 18 fields sampled were all three BSP of the same race. In some fields all three BSP were different races. The variability is further evident in the low percentage of SCP that were the same as the BSP from which they came.

In R4 fields, SCP of R2, R4, and R6 were fairly stable within the fields tested with R2 and R4 predominant. The cultivars Forrest, Pickett, and Centennial have been grown extensively throughout Arkansas for many years (1). These three cultivars have resistance to *H. glycines* R1 and R3 but are good hosts for R2 and R4. As a result, R2 and R4 have become the predominant races in the state.

The most variable populations studied were from fields infested with the Bedford population. Bedford is not a differential, so the BP could be any race. In the BP fields, the races most frequently observed when the BSP and SCP were tested were 2, 4, and 6. These data further support the predominant position of R2 and R4 in soybean fields in Arkansas.

Bedford probably had been grown little in the 12 R3 and R4 fields. Most of the BSP and SCP from those fields, regardless of their race, matured poorly on Bedford (Table 3). In contrast, Bedford probably had been grown extensively in the six BP fields because 78% BSP and 72% SCP had positive MFI on Bedford. Even the R3 from BP fields had an MFI above 10 on Bedford

(Table 3). Race 3 from R3 and R4 fields had MFI below 10 on Bedford (Table 3).

The variability found in the 18 fields tested indicates SCN can adapt to virtually any situation that arises. Not only can it adapt efficiently, the speed at which it changes is equally remarkable. Bedford was released as a commercial cultivar in 1978. It was not grown extensively in Arkansas until 1980. Races able to mature on Bedford appeared in isolated areas in 1982, which indicates the adaptation rate of SCN.

Control of SCN would be much easier if its adaptive capabilities were not so great. The common control measures employed today are crop rotation, resistant cultivars, and nematicides. Crop rotation, used in a 3-year sequence, is very effective in controlling SCN in Arkansas (14). Resistant cultivars are also very effective in controlling SCN; however, the efficiency of this method is reduced if one considers the time involved in developing the cultivar in relation to the time required for SCN to overcome the resistance. The most efficient use of resistant cultivars is in a rotation program.

Information obtained in this study provides an additional basis for recommendations against continuous planting of resistant cultivars. When resistant cultivars were first planted, all were highly resistant. Attempts to increase SCN on resistant cultivars in the greenhouse were unsuccessful (unpubl.). Only after resistant cultivars were planted for 3–6 consecutive years were resistance-breaking races observed (14). As different forms of resistance have been planted, the variability of field populations apparently has become greater.

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