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Complete Characterization of the Race Scheme for *Heterodera glycines*[1]

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Abstract: One hundred thirty-eight isolates of *Heterodera glycines* from nine states in the United States, People's Republic of China, and Indonesia were tested on the four standard soybean race differentials. A total of 12 variants were found, including the five races described previously. The seven variants that did not correspond to one of the described races and reports from other areas of populations that could not be classified are evidence that the present race classification system needs to be fully characterized. Eleven additional races are described; this expands the total to 16 races, the maximum possible using the four prescribed differentials and a + or − rating for each. The seven new races are designated as 6, 9, 10, 13, 14, 15, and 16. This complete characterization of the race scheme will allow for immediate communication of the discovery of the remaining four races plus the identification of previous undescribed races.

Key words: Heterodera glycines, race, soybean, soybean cyst nematode.

Heterodera glycines Ichinohe, the soybean cyst nematode (SCN), was first observed in the United States in North Carolina (15) in 1954. Resistance to SCN was readily available and incorporated into commercial soybean (*Glycine max* (L.) Merr.) (10). Within 5 years of commercial use of resistance, physiological variation was reported in SCN (9). Other variants, based on maturation of SCN females on differential soybean cultivars, were reported (8,12). Physiological strains of SCN were reported from Japan (13), and Miller (6) differentiated 11 groups. A procedure for separating races, using four differentials and a susceptible standard, was established in 1970 (2). Four races were named at that time, and race 5 was added in 1979 (3). Sixteen races were possible with this scheme, but the lack of characterization of them has led to difficulty in communication among breeders, researchers, and others working with SCN. Many populations from Arkansas (7), Florida (4), Indiana (1), Iowa (16), Minnesota (5), and North Carolina (11) are not races 1–5.

Our objective is to designate the remaining 11 races in the scheme proposed by Golden et al. (2).

Materials and Methods

One hundred thirty-eight isolates of SCN were collected from farms in Arkansas, Florida, Illinois, Kentucky, Mississippi, North Carolina, Texas, Virginia, and Wisconsin in the United States and Indonesia and People's Republic of China. The 67 samples obtained by the University of Arkansas were each divided and placed in two 15-cm-d clay pots containing fine sand. Two 'Lee' soybean seedlings were transplanted into each pot and allowed to grow 6 weeks to increase the population. Cysts were obtained by a roiling and sieving method, broken in a blender, and sieved (250-μm-pore) to remove unbroken cysts (7). Each isolate was tested using the original prescribed soybean differentials 'Pickett', 'Peking', PI 88788, and PI 90763 (2). Lee was the standard against which female maturation on each differential was measured. Seeds of the soybean differentials were germinated in vermiculite and transplanted singly into 7.5-cm-d clay pots when cotyledons opened. Each cultivar or line was transplanted into three pots. Plants were inoculated 2 days later with 4,000 eggs and second-stage juveniles in a 10-ml suspension. All plants were grown in a greenhouse at 25–30 C. Thirty days after inoculation, cysts and females were collected and counted. Each pot was processed by

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TABLE 1. Isolates of *Heterodera glycines* tested in each race and range of indices on each differential.

Race	Isolates in race (no.)		Indices range							
			Pickett		Peking		PI 88788		PI 90763	
	AR	NC	AR	NC	AR	NC	AR	NC	AR	NC
1	2	12	4–7	0.7	1	0–3	20–52	22–185	0–0.3	0–4
2	14	24	43–209	11–288	10–48	12–251	10–143	11–366	0–7	0–7
3	6	3	0–8	1	0–3	0–4	0–2	0–6	0–0.4	0–3
4	12	15	21–810	17–319	10–132	17–193	10-261	12–104	10–109	12–123
5	9	8	11–97	11–78	0–6	0–5	12–120	12–98	0–3	0–3
6	7	3	12–57	15–33	0–6	0–3	0–2	2–8	0–3	2–3
7	—	1		0		4		73		13
8	—	—								
9	6	2	44–110	14–47	12–33	10–21	0–6	2–6	1–8	21
10	1	—	1		3		21		13	
11	—	—								
12	—	—								
13	—	—								
14	0	1	27–209	63	15–84	14	0–5	8	10–42	19
15	1	1	25	15	4	0	42	12	19	14
16	—	1		4		14		100		27

AR = Arkansas. NC = North Carolina. — indicates this race was not found.

washing and rubbing the roots to free the females and cysts, suspending the soil and nematodes in water, and sieving the suspension through nested 850-μm-pore and 250-μm-pore sieves.

Some of the 71 isolates collected from North Carolina fields were increased on 'Lee 68' soybean; in others, the differentials were seeded directly in the infested soil. Infested field soil was divided and mixed in equal portions with enough sand to fill 15 7.5-cm-d pots. Soil with isolates increased on Lee 68 was mixed and placed in 15 7.5-cm-d pots. At 30 days after transplanting, nematodes were removed from the roots with a high pressure stream of water and collected on a 250-μm-pore sieve.

At each location the index (I), as used by Golden et al. (2), was calculated as follows:

$$I = \frac{\text{Average number of females and cysts from differential}}{\text{Average number of females and cysts from Lee}} \times 100$$

Each differential was given a + or − rating based on I. The index for each replication was calculated, and the average of three replications determined the index of the differential. The index was rounded to the nearest whole number unless it was less than 0.5. An $I \geq 10$ was assigned a + and an $I < 10$ was assigned a −. This is an arbitrary breaking point based on the assumption of Golden et al. (2) that if as much as 10% maturation occurred the population would readily increase on that differential.

RESULTS AND DISCUSSION

The 138 isolates were separated into 12 distinct groups using the four soybean differentials (Table 1). Of the isolates tested in Arkansas and North Carolina, respectively, 3% and 17% were race 1, 21% and 34% were race 2, 9% and 4% were race 3, 18% and 21% were race 4, and 13% and 11% were race 5. Sixty-four percent of the isolates tested in Arkansas fit into races 1–5, as did 87% of those tested in North Carolina. This means 36% of the isolates tested in Arkansas and 13% of those tested in North Carolina, or 25% of the total populations tested, did not fit these 5 races. In a 1985–86 survey in North Carolina, 23% did not fit (11).

Based on the + and − ratings, there were 33 isolates in seven groups that did not fit

TABLE 2. Full expansion of race classification for *Heterodera glycines* using the host differentials as described by Golden et al. (2).

Race	Reaction on differential			
	Pickett	Peking	PI 88788	PI 90763
1	−	−	+	−
2	+	+	+	−
3	−	−	−	−
4	+	+	+	+
5	+	−	+	−
6	+	−	−	−
7	−	−	+	+
8	−	−	−	+
9	+	+	−	−
10	+	−	−	+
11	−	+	+	−
12	−	+	−	+
13	−	+	−	−
14	+	+	−	+
15	+	−	+	+
16	−	+	+	+

+ = Number of females and cysts recovered was 10% or more of the number on Lee cultivar.
− = Number of females and cysts recovered was less than 10% of the number on Lee.

in one of the described races (Table 1). Twenty-eight of the isolates were in three groups of near equal size and four groups were represented by either one or two isolates. To accommodate these and other isolates that do not fit in the five described races, the race scheme needs to include all 16 of the races that are possible when using four differentials and a + and − rating (Table 2). Based on this classification, 10 isolates were race 6, 1 was race 7, 8 were race 9, 1 was race 10, 10 were race 14, 2 were race 15, and 1 was race 16 (Table 1). In the recent survey in North Carolina (11), eight distinct groups were found. Of 156 isolates, 23% would be classified race 6, 9, or 15.

Isolates fitting the descriptions for races 6, 8, and 9 were reported earlier (7) but were not given a race number. Isolates with the criteria of race 6 were reported from Indiana (1) and race 5 or 15 from Minnesota (5). Isolates fitting criteria for races 9 and 14 were reported in a survey of Florida populations (4).

There was variation among replications, and in certain tests one replication was assigned a +, the other two a −, and vice versa. In these cases the mean I was used to classify the race. The SCN race categories are artificial, being based on relationships established by researchers. Isolates with I $\approx$ 10 may behave in the field as one race or another depending on the environment. A soybean cultivar planted in a field causes shifts in the gene frequency of the isolates (14).

SCN is extremely variable genetically, and these additional race designations are needed so the variants can be classified. The complete characterization of the race scheme to 16 will enable plant breeders to identify resistance to specific races if broad resistance cannot be found. The race classification system needs to be improved, and research is underway to determine which parameters should be used. Until such a system is devised, however, utilization of the race scheme recommended herein will enable researchers, extension personnel, and other advisors to continue the progress that has already been made. In fact, all current cultivars with SCN resistance have been developed using the race scheme of Golden et al. (2). The additional race descriptions should make the current system more useful.

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Note: After this manuscript had been submitted to the printer, the authors were made aware of the following abstract. Chen, P. H., D. S. Zhang, and S. Y. Chen. 198?. First report on a new physiological race (race 7) of soybean cyst nematode (*Heterodera glycines*). Journal of the Chinese Academy of Agricultural Sciences 20:94 (Abstr.). The authors have adjusted their race designations accordingly.