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RACES OF *HETERODERA GLYCINES*[1]

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ABSTRACT

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Soybean cyst nematode (SCN) (*Heterodera glycines*) was found in the United States in 1954. Sine 1965, cultivation of resistant soybean (*Glycine max*) has increased and is now used widely for SCN control. During this time SCN has been shown to be extremely variable. This variability is discussed and an expanded race scheme is shown.

Key Words: genetic variability, *Glycine max, Heterodera glycines,* nematode races, resistance, soybean.

RESUMEN

Riggs, R. D. 1988. Las razas de *Heterodera glycines.* Nematrópica 18: 163–170.

El nematodo del quiste de la soya (*Heterodera glycines*) fue descubierto por primera vez en los Estados Unidos en 1954. El uso de cultivares de soya (*Glycine max*) resistentes al nematodo para su manejo ha ido en aumento desde 1965 cuya práctica es hoy en dia de acceptación general. Durante este período el nematodo ha mostrado una variabilidad extrema sobre la cual se hacen comentarios en el trabajo y se propone un sistema más amplio para la clasificación de las razas.

Palabras claves: Glycine max, Heterodera glycines, razas de nematodos, resistencia, soya, variabilidad genética.

When soybean cyst nematode (SCN) (*Heterodera glycines* Ichinohe) was found in North Carolina in 1954 (35), it had been known in Japan and China for more than 50 years (P. S. Chen, pers. comm.). The use of resistant soybean (*Glycine max* (L.) Merr.) cultivars was not practiced in the Orient until recent years, but land races produced by individual growers may have been resistant. However, SCN races had not been observed. Ross and Brim (29) tested all strains in the USDA germplasm collection and found several that were resistant. Soybean breeders initiated programs to introduce SCN resistance into commercial cultivars. In 1962, the occurrence of "physiological strains" of *H. glycines* was reported (28). Subsequently, variations among 11 isolates of SCN from several states was documented in a series of studies. Of the 11 populations from eight states that were studied, four matured on table beet (*Beta vulgaris* L.). SCN populations MO-1 and VA-4 produced 1–3% as

many females on beet as on 'Lee' (13). The 11 populations reproduced differentially on four species of *Penstemon* (22). On *P. barbatus* (Cav.) Roth, no females were found; on *P. angustifolius* Nutt. ex Pursh, SCN population MS-1 produced a few females whereas VA-1 produced many; on *P. ovatus* Dougl. ex Hook three populations did not reproduce, seven produced at least a few females, and the AR-1 population produced many. On *P. wilcoxi* Rydb. a few females of all 11 isolates matured. Separations among isolates also could be made using *Antirrhinum majus* L. (15); *Phaseolus vulgaris* L. cv. Bountiful; *P. aureus* Roxb. (now *Vigna radiata* (L.) Wilczek) cv. Kiloga; *Vicia villosa* Roth cv. Madison; and *Glycine ussuriensis* Regel & Maack (now *G. soja* Sieb & Zucc.) (16); or *Glycine max* (L.) Merr. cv. Lee, *G. gracilis* Skvortz. (now *G. max*), *Cassia tora* L., *Trifolium hybridum* L. FC 34088, *Vicia sativa* L. cv. Warrior, and *Penstemon grandiflorus* Nutt. (17). All 11 populations were tested on two soybean cultivars ('Peking' and 'Pine Dell Perfection') and six introduced lines (PI 79693, PI 84611, PI 87631-1, PI 88788, PI 90763, and PI 91684) and each isolate could be differentiated as a race based on the numbers of maturing females (18). Pigeon pea (*Cajanus cajan* (L.) Huth) was not a host of five isolates but was a poor to good host of the other six isolates (20). 'Pearson A-1' tomato was a poor to good host of seven isolates but was not a host of three isolates (21). There was a wide range in morphometric variation among isolates, but the differences were not sufficient to propose new species (23). Miller felt the differences were great enough to indicate that the isolates were geographical races. Miller selected seven single cysts from one field, increased each separately, and inoculated 'Lee', 'Peking', PI 79693, and PI 90763 soybeans with each culture (19). Using a + and − rating based on $> 10\%$ or $< 10\%$ of the number of females that developed on 'Lee', the seven populations could be separated into five races. The numbers of females on 'Lee' differed sufficiently that four groups could be distinguished. Smart (31) reported additional physiological variation from Virginia and Sugiyama et al. (32) reported a physiological variant on soybean in Japan.

In 1969, a committee of soybean breeders and nematologists met to discuss variability in *H. glycines*. The members felt that infraspecific forms should be called races and would be distinguished with a combination of soybean cultivars and introduced soybean lines (5). The cultivars 'Pickett' and 'Peking', and the introduced lines PI 88788 and PI 90763 were selected as differentials. 'Lee' (not 'Lee 68' or 'Lee 74') soybean was selected as the susceptible cultivar against which the differentials were rated. Even though Miller found significant differences in the reproduction of populations on 'Lee', through the years reproduction on this cultivar has been remarkably consistent. The races were distinguished on the basis of either a + or − rating on each of the four differentials. A + indicated that the number of females and cysts reco-

vered from the differential was ≥ 10% of the number on 'Lee'; a − indicated that the number on the differential was < 10% of the number on 'Lee'. The 10% level was chosen as the breaking point by the committee. They felt they could not use 0 females for resistant and 1 female or more for susceptible because no soybean cultivars or lines were known on which no females matured. They also thought that any time there was as much as 10% as many females on the differential as on 'Lee', a population would probably build up quickly on the resistant line.

The race scheme using four races was published in 1970 (Table 1)(5). The committee intended for the scheme to be open-ended and new races could be added as they were found. From 1970 to 1988 only two additional races were described (3,9). In 1988 the 16 races possible using four differentials and a + and − rating system were characterized (Table 1)(27). The additional descriptions were needed to accommodate the many reports of populations that could not be characterized as races 1–5.

The host differentials were selected on the basis of their resistance to *H. glycines*. 'Peking' and PI 90763 were reported to have similar resis-

Table 1. Reactions of races of *Heterodera glycines* on host differentials.

Race[z]	Reaction[y]			
	'Pickett'	'Peking'	PI 88788	PI 90763
1	−	−	+	−
2	+	+	+	−
3	−	−	−	−
4	+	+	+	+
5	+	−	+	−
6	+	−	−	−
7	−	−	+	+
8	−	−	−	+
9	+	+	−	−
10	+	−	−	+
11	−	+	+	−
12	−	+	−	+
13	−	+	−	−
14	+	+	−	+
15	+	−	+	+
16	−	+	+	+

[y] − = < 10% of the number of females and/or cysts on 'Lee' soybean; + = 10% or more of the number of females and/or cysts on 'Lee' soybean.

[z] Races 1–4 according to Golden et al. (5); race 5 according to Inagaki (9); race 7 according to Chen et al. (3); races 6 and 8–16 according to Riggs and Schmitt (27).

tance (29). 'Pickett' is a derivative of 'Peking' but does not have the same level of resistance as 'Peking' (R. D. Riggs, unpubl.). PI 88788 has resistant genes some of which are different from those in 'Peking' and PI 90763 (7,33). Until recently these were the only sources of resistance to SCN that had been used in developing SCN-resistant cultivars. Miller (pers. comm.) found some level of resistance to SCN in 'Ilsoy', PI 79693, PI 84611, PI 84751, PI 87631-1, PI 91684 and PI 209332. 'Cloud', 'Columbia', and PI 89772 also have differential resistance and recently a number of soybean lines were reported by Anand and Gallo (1) to have some resistance to race 3, 4 or 5 (Table 2). PI 437654 has the highest level against all three races.

The currently grown resistant cultivars, in many cases, have different levels of resistance than the resistant parent. There are also reports of cultivars or lines that are more susceptible than 'Lee' that could be used as the susceptible check. All of the soybean cultivars or lines with some

Table 2. Grouping of soybean lines and reaction to *Heterodera glycines* race 3, 4[x] and 5[y].

	Group	Line		Group	Line
1.	R-R-R[z]	PI 437654	12.	R-S-MS	PI 437725
2.	R-MR-R	PI 404198B			PI 438497
3.	R-R-MS	PI 438503B			PI 438498
4.	R-MS-MR	PI 339868B	13.	R-S-S	Columbia
5.	R-R-S	PI 87631-1			PI 92702
		PI 88788			PI 303652
		PI 209332			PI 428896B
		PI 398680	14.	MR-S-MS	PI 200495
6.	R-MR-MS	Ilsoy			PI 417091
		PI 404198B	15.	MR-S-S	PI 54591
		PI 407729			Patoka
		PI 416762			PI 79693
		PI 437655			PI 89008
7.	R-S-R	PI 89772			PI 89014
		PI 90763			PI 9118
		PI 404166			PI 398682
		PI 438489B			PI 407944
8.	R-MR-S	Cloud			PI 408192-2
9.	R-MS-S	PI 79609			PI 417094
10.	MR-MR-S	PI 437770			PI 437488
11.	R-S-MR	Peking			PI 438183
		PI 84751			
		PI 437679			
		PI 437690			

[x]This was not race 4 because PI 88788 was reported to be resistant.
[y]From Anand and Gallo (1).
[z]The first letter in each group represents the reaction to race 3, the second race 4 and the third race 5.

level of resistance are candidates for use as host differentials for race determination. Expansion of the number of differentials increases the number of races that can be identified (26). There has been discussion of changing the differentials. For example, because 'Pickett' is a derivative of 'Peking' some feel it should not be a differential; others feel that because 'Pickett' does not have the same complement of genes for resistance, it should be a differential. Whether the differentials should be changed needs to be considered carefully, and if a change is made, it should be done only after the data and purpose are evaluated thoroughly.

Anand and Gallo (1) tested 9153 soybean lines against *H. glycines* races 3, 4 (actually not race 4 because PI 88788 was resistant, but the race could not be determined because 'Pickett' was not included), and 5 and found 45 lines with some level of resistance against one or more of these three races. The reactions of the lines tested by Anand and Gallo can be placed into 15 categories (Table 2). Assuming that all lines within any one reaction group are identical, a reasonable and logical selection could be made from each group. To determine the genotypic differences among the selections, crosses would be made between pairs in all possible combinations and progeny and backcrosses obtained. Of course this would be a major undertaking and it would not include groups that might be formed if races 1 and 2 were tested. The research would become more difficult if all 16 races were included. The objective would be to obtain a number of lines with single-gene differences that could be used as differentials. That would allow a more precise determination of races, but considerably more work would be involved. Ideally, host differentiation of the SCN races would be accomplished using soybean lines on which no females mature if the line is resistant and many females mature if it is susceptible. The probability of finding such lines seems remote.

DNA analyses may eventually be useful for separation of races, but in one study the separations that could be made did not conform to the races as now defined (24). In another study races 3, 4 and 5 could be separated, but only one population of each was studied (10). Immunoelectrophoretic separation has been attempted, but success was limited (6). In tandem crossed immunoelectrophoresis races 3 and 4 were separated but the process was so complicated that it is not practical.

Triantaphyllou (34) proposed that races be determined by gene frequencies for parasitism. Few studies have been conducted on the inheritance of genetic capabilities, but it is probably related to the inheritance of resistance in soybean. Caldwell et al. (2) determined that three recessive genes were involved in resistance to race 1, and a dominant gene for resistance was added by Matson and Williams (12). Another recessive gene governs resistance to race 4 (8), probably the one present in PI

88788 (33). PI 90763 has a dominant gene for susceptibility which may be an allele of the recessive gene for resistance in PI 88788. PI 90763 has two recessive genes and one dominant one for resistance (3). Resistance to a race 2 that reproduces on 'Bedford' is controlled by a single recessive gene and resistance to race 14 is conditioned by an allele that is dominant to the gene for resistance to race 2 (7). A gene for zero-level production of females and cysts (11), if universal against all races, would eliminate the selection of races. If the zero-level gene is transferred into all soybean cultivars, reproduction of SCN would be eliminated.

Soybean cultivars with the common genes for resistance can be placed into three groups: 1) cvs. Peking, Pickett, Pickett 71, and Forrest; 2) PI 63468, PI 87628, PI 87631-1, PI 88788, PI 209332, and 'Cloud'; and 3) PI 89772 and PI 90763 (35). In order to determine the exact genotypic differences among these groups, genetically homogenous populations of nematodes are needed. This is the only way to identify physiological infraspecific genotypes. To obtain homogenous populations of nematodes, either sibling matings or father-daughter matings would be necessary over many generations to reduce heterogeneity. Alternatively, either single cysts or pairs of sibling juveniles could be selected and increased over a period of time. Mating of selected individuals should provide homogeneity faster but would be more difficult.

The identification of genotypes may be possible by using isozyme markers, DNA analyses, and host differentiation or various combinations of these techniques. Protocols are available for isozyme analyses of single females. The eggs from these same females could be placed on a host to increase the population and the race of the progeny determined. This would not be a simple procedure but could be used for very precise identification of populations used for studies on genetics of parasitism.

Triantaphyllou (35) suggested a system which would use host, biotype, and relative degree of parasitism for naming races (field populations) of *H. glycines*. The system would become quite complex but would provide unlimited possibilities for expansion. The race names would give certain information about the relationship of the populations to the various types of resistance. This proposal has merit and probably would be more useful for research identification of races but eventually could be modified for use by advisory purposes.

For the present, the current system as expanded provides a tool for the identification of field populations. The field population may be a mixture of genotypes but, by nature of the definition, the population would be classified as a single race. The gene frequencies in field populations may change as host cultivars change, but the differentials will still identify the race present, and thus the dominant genotype, at any particular time. Until genotypes are identifiable the differential host test should remain useful. The history of SCN race designations is marked

by tremendous successes of advisory services and in the release of high-yielding resistant cultivars.

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