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Variation in Parasitic Potential of *Heterodera glycines* Populations

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ABSTRACT

A great deal of variation in parasitic potential has been observed among the soybean cyst nematode (SCN) *Heterodera glycines* Ichinohe populations in the USA. To best utilize sources of genetic resistance to SCN, this variation needs to be characterized. Fifty-eight populations of the SCN were collected from 10 major soybean producing states. These populations were compared for infraspecific variation in parasitic potential on soybean [*Glycine max* (L.) Merr.] genotypes 'Peking', 'Pickett', Plant Introduction (PI) 88788, PI 90763, and 'Lee 68'. Race structure, genes for parasitism (capability of a nematode population to produce at least one cyst on a resistant genotype), and levels of parasitism (percentage of cysts that developed on resistant genotypes compared with the susceptible cultivar Lee 68) were assessed. Race 3 was present in 45% of locations; it was the most widespread population. Race 6 was present in 19% of the locations. Frequency of occurrence of other races (Races 1, 2, 5, 9, and 14) ranged between 3 and 9%. On the basis of reproduction on genotypes, 83% of the populations tested had genes to parasitize Pickett. All populations from Arkansas, Florida, Georgia, Iowa, North Carolina, and South Carolina produced cysts on this genotype. Average level of parasitism was greatest on Pickett and lowest on PI 90763; 91% of SCN populations tested had <10% level of parasitism on PI 90763. The SCN gene frequencies demonstrated that nematode populations with predominant genes for parasitism on Pickett and Lee 68 were widespread especially in the southern soybean producing states in the USA. Cultivation of varieties with resistance derived from Peking and Pickett in these regions should not be very effective. For management of SCN-caused yield losses, cultivation of soybean varieties with resistance derived from PI 90763, PI 88788, and PI 437654 should be encouraged.

SOYBEAN CYST NEMATODE (SCN), *Heterodera glycines* Ichinohe, is widely distributed in the major soybean growing regions of the USA. In 1979, the damage due to SCN was estimated at 1.52 million tons with a value of more than $420 million (4). Economic losses caused by the nematode in the southern states have gradually declined primarily due to cultivation of nematode resistant soybean cultivars (12). However, in recent years, SCN has been recognized as a major pest in the northern soybean producing states causing an estimated annual loss of more than $267 million (5). Cultivation of nematode resistant soybean cultivars is one of the standard methods to reduce yield suppression by this nematode. It is estimated that cultivation of the resistant cultivar Forrest prevented crop losses worth $405 million between 1975 and 1980 (3). There are currently more than 130 commercial SCN resistant cultivars in the USA (1), but resistance in most cultivars is not durable because of the dynamic nature of SCN populations with respect to their ability to parasitize resistant cultivars (2, 7, 9, 13). Golden et al. (6) identified four races of the nematode based on the ability of SCN populations to reproduce on four selected soybean differentials. Using the same four genotypes, Riggs and Schmitt (10) proposed 16 races based on a quantitative comparison of cyst reproduction on the four differentials with that on susceptible Lee. The practical function of the race characterization scheme in nematode management advisory programs is rather limited because of recurrent changes in the race structure of nematode populations within a field. Anand (1) studied the race structure of an SCN population in southeast Missouri by growing the soybean cultivar Bedford, which is resistant to Race 3 and 14 of SCN continuously in the same field. Initially, Race 14 was present in the field, and after 2 yr, the population was classified as Race 4. After 3 yr in Bedford, the nematode population was categorized as Race 2, and after 5 yr, it became Race 5. Similar changes were reported by Triantaphyllou (13).

The objectives of this investigation were to understand the infraspecific variation in SCN populations from 58 locations within 10 states constituting the major production areas of the USA, determine the abilities of diverse SCN populations to reproduce on different sources of resistance, and to study the effectiveness of the commonly used resistant germplasm in soybean cultivar development programs in management of SCN-caused losses.

MATERIALS AND METHODS

Soil samples were collected during July and August of 1988 and 1989 from fields that had a history of SCN infestation. This included 2 locations each in Arkansas, Georgia, Iowa, and Ohio, 3 locations in Florida, 6 locations in South Carolina, 9 locations each in Tennessee and North Carolina, 11 locations in Missouri, and 12 locations in Illinois. The soil samples were processed using a semiautomatic elutriator, and cysts were extracted on a 250-μm (60 mesh) sieve and counted with a stereo microscope (8). All samples with at least 20 cysts 225 cm^{-3} of soil were studied. Soil samples with higher cyst counts were adjusted to 20 cysts 225 cm^{-3} of soil by mixing with appropriate quantities of steam sterilized soil. Seeds of SCN differentials Pickett, Peking, PI 88788, PI 90763, and susceptible Lee 68 were germinated in vermiculite. The seedlings with ≈3-cm-long radicals were transplanted singly in 7.5-cm-diam. pots containing different soil populations. Plants were grown in a greenhouse maintained at 27±2°C for 30 d. Plant roots were washed with a jet of water, and cysts (white females) were dislodged and counted with aid of a stereobinocular microscope. There were five replications (plants) of each host, and the test was repeated.

The number of cysts per root from all five plants were averaged. Each SCN population was classified as a race based on the index of parasitism using mean number of cysts on 10 plants (6, 10). In addition, any SCN population that produced at least one cyst on a given differential was considered to have gene(s) for parasitism on that genotype. The level of parasitism of each SCN population on each of the host differentials was calculated as percentage of cysts that developed on Lee 68.

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Abbreviations: SCN, soybean cyst nematode; PI, plant introduction.

Table 1. The range of number of cysts on Lee 68, the range of index of parasitism on soybean cyst nematode differentials, and the resulting race designations of 58 soybean cyst nematode populations sampled in 10 states.

State and county	Lee 68 cyst number†	Pickett	Peking	PI 88788	PI 90763	Race§
		% of cysts produced on Lee 68‡				
North Carolina						
Craven	147-177	38-48	18-22	18-26	0¶	2
Johnson	182-196	39-42	+ +#	+ +	0	6
Wilson	165-175	55-62	2-3	0-1	0	6
Greene	163-179	51-59	0-1	1-1	1	6
Beaufort	158-183	48-57	1-4	16-28	2-4	5
Beaufort	104-134	35-44	13-15	10-19	0	2
Washington	166-194	28-31	0-1	3-5	0	6
Wayne	167-191	18-25	0	19-25	0	5
Pasquotank	132-140	70-82	+ +	0	0	6
Missouri						
Pemiscot	130-148	66-87	44-57	58-61	1	2
Scott	260-297	+ +	+ +	1-1	+ +	3
Scott	210-222	1-4	0	0-2	9	3
Stoddard	130-137	0	+ +	0	0	3
New Madrid	98-106	138-147	12-19	+ +	3-9	9
New Madrid	138-156	+ +	3-6	12-18	0	1
Dunklin	160-173	55-59	11-19	+ +	1-6	9
Boone	109-127	83-95	53-71	64-76	+ +	2
Boone	260-293	+ +	+ +	0-1	+ +	3
Cape Girardeau	178-184	0	0	0	0	3
Cape Girardeau	111-125	4	0	10-13	0	1
Illinois						
Douglas	202-230	0	+ +	0	+ +	3
Coles	160-166	0	+ +	3-6	0	3
Shelby	160-179	0-1	1-3	1-1	+ +	3
Franklin	123-135	18-32	9-16	+ +	+ +	9
Washington	141-158	1-1	+ +	0-1	0	3
Williamson	200-211	136-158	58-73	2-5	4-9	9
Jackson	209-229	122-158	55-59	2-4	8-9	9
Effingham	140-152	0	0	0-3	0	3
Effingham	178-198	+ +	+ +	0	0	3
Effingham	179-202	6-9	2-5	+ +	+ +	3
Pulaski	121-144	+ +	0	+ +	0	3
Jackson	175-195	0	0	0	0	3
South Carolina						
Orangeburg	163-176	6-9	3-7	0-1	0	3
Orangeburg	114-127	11-19	1-1	+ +	1-4	6
Orangeburg	116-120	64-67	18-24	4-4	17-18	9
Florwel	149-162	39-48	17-27	0-1	2-3	14
Marion	168-181	2-3	2-2	2-4	0	3
Darlington	122-137	11-16	1-1	0-2	0-1	6
Tennessee						
Gibson	140-178	4-7	+ +	0-1	0-2	3
Madison	148-166	44-58	55-62	2-3	47-53	14
Madison	420-443	0	+ +	+ +	0	3
Dyer	118-140	3-5	0	0	0	3
Dyer	143-152	4-7	+ +	0-1	+ +	3
Dyer	138-165	1-3	0	0-2	0	3
Jackson	445-464	9-17	2-5	4-7	5-8	6
Lawrence	438-455	0	0	0	0	3
Obion	123-151	22-28	33-38	2-3	18-22	14
Georgia						
Clarke	213-244	58-63	8-18	7-9	10-14	14
Clarke	202-236	50-66	12-18	7-8	11-15	14
Iowa						
Hancock	101-160	3-5	+ +	2-6	+ +	3
Story	121-157	3-8	0	2-8	0	3
Ohio						
Fayette	222-240	0	0	0	0	3
Fayette	233-257	0	0	0	0	3
Florida						
Jackson	112-139	38-46	1-3	0-1	0-2	6
Gadsden	126-143	14-21	3-7	1-1	+ +	6
Gadsden	122-132	18-22	1-3	2-6	+ +	6
Arkansas						
Mississippi	256-305	55-67	23-29	14-18	4-5	2
Crittenden	187-214	58-60	25-28	+ +	8-10	9

† Number of cysts produced on Lee 68 after 30 d.
‡ Level of parasitism on the resistant genotypes was measured as percentage of cysts that developed on susceptible cultivar Lee 68. Each value in the range is from one replication and represents the mean of five plants.
§ Race characterization by Riggs and Schmitt (10).
¶ 0 = No cyst was produced.
# Cysts were produced and the population was considered to have genes for parasitism on that differential, but level of parasitism was less than 1.0% of that on Lee 68.

RESULTS

SCN Race Distribution

Race 3 was the most widespread race in Missouri, Illinois, Tennessee, Iowa, and Ohio (Table 1). This race was not present in the locations surveyed in Georgia, Florida, and Arkansas. Race 1 was found only in Missouri; Race 2 in North Carolina, Missouri, and Arkansas; Race 5 in North Carolina and Illinois; Race 6 in South Carolina, North Carolina, Tennessee, and Florida; Race 9 in Arkansas, Illinois, Missouri, and South Carolina; and Race 14 in Georgia, Tennessee, and South Carolina. Frequency of occurrence of Races 1, 2, 3, 5, 6, 9, and 14 was 3, 7, 45, 3, 19, 9, and 9%, respectively.

Genes for Parasitism

The SCN populations with genes for parasitism on Pickett were found in 9 out of 10 states (Table 1), and 83% of the populations reproduced on this cultivar at least at low levels. All of the populations in North Carolina, Georgia, Florida, and Arkansas had genes for parasitism on Pickett. The SCN populations with genes for parasitism on Peking came from 70% of the locations. Populations with genes for parasitism on PI 90763 were lower in frequency, and 43% of the populations did not reproduce on this genotype.

About 56% of the SCN populations had genes for parasitism on all four resistant differentials whereas 8% of the populations did not parasitize any of these genotypes. Two populations reproduced only on Pickett and Peking, one population reproduced only on PI 90763 and Peking, and five populations reproduced only on PI 88788 and Pickett. None of the populations reproduced only on PI 90763 and Pickett. There were three populations, in Missouri, Illinois, and Tennessee, that reproduced only on Lee 68.

Level of Parasitism

The average level of parasitism on Pickett was 29, which indicated that cyst production on Pickett was 29%

of the cyst number on susceptible Lee 68. The levels of parasitism from one location in New Madrid County in Missouri and in Williamson and Jackson Counties in Illinois were greater on Pickett than on Lee 68. The level of parasitism on Peking was greatest in one of the samples in Boone County in Missouri and in Williamson County in Illinois. Although the level of parasitism on Peking was generally lower than that on Pickett, four populations that did not reproduce on Pickett produced low numbers of cysts on Peking. Eighty-four percent of the populations that developed on PI 88788 and 91% of those developed on PI 90763 produced fewer than 10% of the number of cysts produced on Lee 68. The levels of parasitism of two SCN populations in Boone and Pemiscot Counties in Missouri on PI 88788 and of one population in Madison County in Tennessee on PI 90763 were very different (much higher) than SCN populations from other locations (Table 1). Thirty-eight percent of the populations on Pickett and 10% on Peking had levels of parasitism >30. On the other hand, only 3% of the populations on PI 88788 and 2% on PI 90763 had a level of parasitism >30.

DISCUSSION

Assessment of gene frequencies for parasitism is a sound basis for understanding SCN population structure even though no individual genes have been identified (7). This study showed that genes for parasitism on Pickett were widespread among the SCN populations in some of the major soybean growing states. Cultivation of soybean cultivars with resistance genes derived from Pickett is liable to be less effective in reducing damage caused by SCN than production of cultivars with resistance derived from PI 90763. On the basis of the current race characterization scheme (10), cultivars with resistance derived from any of the four differentials could be recommended in soil with predominantly SCN Race 3. However, it is clear from the data on genes for parasitism and levels of parasitism that resistance derived from Pickett and Peking will not be as effective as resistance derived from PI 88788 and 90763.

For nematode management advisory programs, we believe that utilization of the concept of *greatest and lowest frequencies of genes for parasitism* will provide significant assistance in recommendation of soybean cultivars for SCN infested fields. If, for example, the greatest number of cysts are produced on Peking, then it is implied that genes for parasitism on Peking are predominant in the SCN population, and if cyst number is lowest on PI 88788, then cultivars with resistance derived from PI 88788 could be recommended for cultivation. If level of parasitism of a population on all the resistant differentials is <10, it can be characterized as a population with predominant genes for parasitism on Lee 68. However, if the level of parasitism is >30 (11) and if no perceptible difference is observed between the greatest and lowest cyst numbers on these differentials, then other management options such as chemical control and crop rotation may be suggested. Use of cultivars with resistance derived from other resistant sources such as PI 437654 (1) will be necessary before resistant cultivars could be used as an option.

We conclude that SCN populations with predominant genes for parasitism on Pickett and Lee 68 are widespread in the surveyed soybean production regions of the United States. Cultivation of soybean cultivars with resistance derived from PI 88788, 90763, and 437654 should be encouraged in these states.

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