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Changes in Reproduction of a *Heterodera glycines* Race 5 Isolate Cultured on 'Cordell' and 'Bedford' Soybean

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Abstract: Isolates from a race 5 field population of *Heterodera glycines* were cultured separately on soybean cultivars 'Bedford' (resistance derived from Peking and plant introduction [PI] 88788) and 'Cordell' (resistance derived from 'Peking', PI 88788, and PI 90763) for 10, 12, and 14 generations. Reproduction was measured of the 10th, 12th, and 14th generations on Bedford and Cordell and on Peking, 'Pickett', PI 88788, PI 90763, and 'Lee' (the soybean lines that are used to determine *H. glycines* race). The isolate cultured on Bedford remained race 5, whereas the isolate cultured on Cordell changed to race 14, to which Bedford is moderately resistant. Cordell probably derived its race 5 resistance from either Peking or PI 90763 because the isolate resulting from culture on Cordell reproduced on the *H. glycines* race differentials in a pattern similar to those of other isolates selected on PI 90763 in previous studies. Rotation of cultivars with pedigrees similar to Bedford and Cordell may be effective in managing *H. glycines* to prevent yield suppression in soybean and the development of new races.

Key words: Glycine max, Heterodera glycines, nematode, race, resistance, selection, soybean, soybean cyst nematode.

The soybean cyst nematode, *Heterodera glycines,* is a major pest of soybean, *Glycine max,* in the United States. Planting resistant soybean cultivars and rotating soybean with nonhost crops are the primary tactics used to limit yield suppression by the nematode. Culture on resistant cultivars increases the nematode's ability to reproduce on these cultivars (1,6–8,12–15). Luedders (5) proposed two genetic groups with cultivars developed from either plant introduction (PI) 88788 or PI 209332 in one group and cultivars developed from either 'Peking' or PI 90763 in the other because *H. glycines* reproduction decreased on cultivars in one genetic group when it increased on cultivars in the second group. 'Bedford' (3) soybean has both Peking and PI 88788 in its pedigree but was similar to PI 88788 as a host for *H. glycines* in nematode selection experiments (13,15). Recently, 'Cordell' (4) soybean, resistant to race 5, was released. The race 5-resistant parent of Cordell, D72-8927, has both Peking and PI 90763 (both resistant to race 5) in its pedigree. The other parent was Bedford. It is not known whether Cordell expresses resistance similar to Peking or PI 90763 or represents a unique recombination between D72-8927 and Bedford. The objective of this experiment was to determine whether Cordell could be placed in one of the two genetic groups proposed by Luedders (5) through selection of an isolate from a race 5 field population of *H. glycines* and measuring reproduction of the resultant progeny on Bedford, Cordell, and other soybean lines.

MATERIALS AND METHODS

In 1985, *H. glycines* was identified from a field near Wheatley, Arkansas, where Bedford soybean had been planted for 5 previous years. Bedford was first planted in 1979 because the field was infested with a population that was suppressing yield of 'Forrest' soybean, which is resistant to race 3. An isolate from the field population was increased quarterly on Bedford from 1985–1989. Infested soil was stored in a cold room at 10 C and 40% relative humidity between periods of increase. Before the experiment was initiated, development of females on each of seven soybean lines ('Lee', 'Pickett', Peking, PI 88788, PI 90763, Bedford, and Cordell) was measured for the Wheatley isolate. Each soybean line was replicated five times. Eggs were obtained from females washed from roots of 35-day-old, greenhouse-grown Bedford soybean plants. Eggs were re-

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leased from females by crushing with a Ten-Broeck tissue grinder. The soybean lines were grown for 30 days in 175 cm^3 sterilized soil (49% sand, 42% silt, and 9% clay) infested with 1,000 eggs of the nematode. Soil was loosened from roots by crumbling the root ball by hand over the funnel of an elutriator (2), and roots were hand-rubbed while submersed in water in the elutriation funnel to help remove females during elutriation of females from soil. Twenty percent of the females were collected on a 250-μm-pore sieve after passing through the sample splitter on the elutriator. Females were counted with aid of a stereoscopic microscope and a gridded dish.

The experiment was initiated by culturing three replications of the Wheatley isolate on either Bedford or Cordell soybean for 35 days in 7.5-cm-d pots (175 cm^3); soil in each pot was infested at planting with 2,000 eggs. Each replication of a soybean cultivar consisted of 14 pots, with two plants per pot. Females were dislodged from soil and roots with a strong water spray and were collected on a 250-μm-pore sieve. Females were hand-picked and used to infest steam-sterilized soil to start the next generation for each replication. At 35-day intervals, eggs from 10 to 100 crushed females were used as inoculum per replication to start the next culture generation in one to five pots per replication, depending on number of available eggs.

After 10 generations, development of females was determined on each of the seven soybean lines used to characterize the Wheatley isolate. Each pot was infested with 1,000 eggs for each of the isolates cultured on Bedford or Cordell. Each treatment was replicated three times in a split-plot arrangement on a greenhouse bench. Nematodes selected on Bedford or Cordell were main plots, and soybean lines on which the isolates were evaluated for reproduction were subplots. Each replicate consisted of four pots of each soybean line with two plants per pot. Plants were grown for 30 days at approximately 28 C. Females were harvested from plants by elutriation of the soil and roots as described for the Wheatley isolate. Number of females on each soybean was expressed as a female index (FI) calculated as the percentage of females that developed on Lee soybean, a standard susceptible cultivar (9), in each replication. Determination of FI of the two isolates on the seven soybean lines was repeated after 12 and 14 generations of selection.

Data from characterization of the Bedford and Cordell isolates for the three periods of selection were combined for analysis of variance using a split-split plot arrangement of treatments where isolate was the main plot, subplot was generation of selection (which was a repeated measure of isolate), and sub-subplot was soybean line. The combined analysis was used because significant differences were not detected among the different times of selection. Effects due to nematode isolates and soybean lines were considered fixed. Analysis of variance and mean comparisons were performed on log transformed values ($\log_{10}$ [FI + 1]. Transformation of the data reduced the correlation of means and variances, and homogeneous variances were obtained. Untransformed values are presented in Table 1 to aid comprehension.

Results and Discussion

The Bedford isolate remained race 5; however, the Cordell isolate changed to race 14 (Table 1), to which Bedford is moderately resistant [FI of 10–30 (10)]. The Cordell isolate had FI $\geq$ 10 on Peking and PI 90763 and FI $<$ 10 on PI 88788. Converse reactions were observed for the Wheatley and Bedford isolates. The differences in FI on Peking, PI 88788, and PI 90763 among isolates resulted in different race designations. Significant differences in FI were observed between the Bedford and Cordell isolates on all soybean lines except Pickett.

Although Cordell has parents from both of the genetic groups proposed by Luedders (5), the FI of the Cordell isolate on

TABLE 1. Female indices (FI), the percentage of females that developed on Lee soybean, on six soybean lines for a *Heterodera glycines* isolate at the beginning of the experiment and after 10, 12, and 14 generations of selection on either Bedford or Cordell soybean, and expected FI for races 5 and 14.

Soybean	Wheatley isolate	Wheatley isolate cultured on		Expected FI	
		Bedford	Cordell	Race 5	Race 14
Pickett	74 ± 62 ab†	46 ± 18 b	99 ± 17 a‡	≥10§	≥10
Peking	6 ± 9 d	4 ± 3 c	27 ± 8 b*	<10	≥10
PI 88788	41 ± 26 b	56 ± 17 b	7 ± 5 d*	≥10	<10
PI 90763	0 ± 1 e	1 ± 1 d	24 ± 5 b*	<10	≥10
Bedford	106 ± 79 a	91 ± 27 a	13 ± 16 c*	—	—
Cordell	10 ± 11 c	6 ± 4 c	77 ± 5 a*	—	—

Data are means ± standard deviation of FI for Wheatley isolate (n = 5) and for the selected isolates (n = 9 each). Actual numbers of females on Lee were 119, 214, and 366, respectively, for the Wheatley, Bedford, and Cordell isolates.

† Means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Fisher's protected LSD after analysis of $\log_{10}$ [FI + 1] transformed data. Values reported are observed means, not antilogs.

‡ Means in the Cordell column followed by an asterisk are significantly different ($P < 0.05$) from the means in the Bedford column for each soybean line according to analysis of log-transformed data. Means reported are observed values, not antilogs.

§ Values in race 5 and 14 columns are the FI used to distinguish between the two races, except Bedford and Cordell are not race differentials; expected FI for races 5 and 14 are according to Riggs and Schmitt (9).

Peking, PI 88788, and PI 90763 places Cordell in the genetic group with Peking and PI 90763. These results support evidence of an allelic series at a common locus in PI 88788 and PI 90763. Thomas et al. (11) proposed an allelic series with dominance in the order of Peking > PI 90763 > PI 88788. This allelic series may be the biological basis for the two genetic groups. The data also supports proposals (5,13), to rotate cultivars with sources of resistance derived from plant introductions in the two genetic groups for management of the nematode; however, supporting field studies are lacking. Timing cultivar rotation could be critical to avoid yield suppression on one or both cultivars. Such rotations probably will have to be coupled with practices that maintain population density below the economic threshold.

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