

## Genetics of Resistance to Physiologic Races of *Phytophthora megasperma* var. *sojae* in the Soybean Cultivar Tracy

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### ABSTRACT

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Inheritance of resistance to *Phytophthora megasperma* var. *sojae* was studied in the F<sub>2</sub> and F<sub>3</sub> generations from the cross of the soybean cultivar Tracy (resistant to all nine reported physiologic races) with PI 360952 (susceptible to all races). The F<sub>2</sub> populations segregated in a 3:1 ratio of resistant/susceptible to races 2, 6, and 7 and segregated in a 15:1 ratio of resistant/susceptible to races 1, 3, 4, 5, 8, and 9. Data from F<sub>2</sub> plants, substantiated by the disease reaction of their F<sub>3</sub> progenies, indicated two independent, dominant genes for resistance in Tracy. One gene controls

resistance to races 1, 2, 3, 4, 5, 8, and 9. It apparently was derived from PI 171442, a progenitor of Tracy, which has the gene *Rps*<sub>3</sub> and is resistant to all races but 6 and 7. The other gene for resistance in Tracy probably derived from D60-9647, the other parent of Tracy, which has the gene *Rps*<sub>1</sub><sup>b</sup> and is resistant to all races but race 2. Lines presumably with the genotype *Rps*<sub>1</sub><sup>b</sup>*Rps*<sub>1</sub><sup>b</sup>*Rps*<sub>3</sub>*Rps*<sub>3</sub> were selected that are resistant to the nine races of the pathogen and are adapted to the Midwest.

*Additional key words:* *Glycine max*, soybean disease.

Seven new physiologic races of *Phytophthora megasperma* Drechs. var. *sojae* A. A. Hildeb., the causal agent of Phytophthora root rot of soybean *Glycine max* (L.) Merr., were found between 1971 and 1975 (1,3,6,7). Through interchange of cultures and information, soybean cultivars resistant to races 1 though 9 were identified before the formal publication of all the new races. One of the resistant cultivars, Tracy, is a commercial variety in the southern United States. Although Tracy is not adapted to the latitude of Indiana, we crossed it with several early maturing cultivars in the greenhouse to select resistant lines of adapted maturity. Data on the inheritance of resistance in the F<sub>2</sub> population and F<sub>3</sub> progenies from one of these crosses are reported.

### MATERIALS AND METHODS

Tracy was crossed with PI 360952, which is susceptible to all races. The F<sub>2</sub> seedlings were inoculated with races 1 through 9. Approximately 12 F<sub>3</sub> seedlings from 100 F<sub>2</sub> plants from the cross PI 360952 × Tracy were inoculated with each race to verify the segregation in the F<sub>2</sub> population.

Inoculum of *P. megasperma* var. *sojae* was prepared by growing isolates of the respective races on oatmeal agar in petri dishes for 2-3 wk at 24 C. One isolate of each race was used. Inoculations were made by inserting a piece of mycelium (2 × 2 mm) in a longitudinal slit in the hypocotyl and covering this with petrolatum to prevent desiccation of the inoculum and plant tissues. Ten-day-old seedlings of the F<sub>2</sub> and F<sub>3</sub> generations and appropriate parental checks were inoculated and incubated in the greenhouse at 24-27 C. Six days after inoculation the seedlings were classified as resistant (no external symptoms) or susceptible (dead).

Data from the F<sub>2</sub> and F<sub>3</sub> generations were analyzed by the chi-square ( $\chi^2$ ) test for goodness of fit to hypothesized ratios.

### RESULTS

The F<sub>2</sub> populations from the cross of PI 360952 × Tracy segregated in a 15:1 ratio of resistant/susceptible to races 1, 3, 4, 5, 8, and 9 of *P. megasperma* var. *sojae* and segregated in a 3:1 ratio of resistant/susceptible to races 2, 6, and 7 (Table 1). These data

indicate two dominant genes for resistance in Tracy to races 1, 3, 4, 5, 8, and 9 but only one dominant gene for resistance to races 2, 6, and 7.

As tested by their F<sub>3</sub> progenies, the F<sub>2</sub> plants from the cross PI 360952 × Tracy segregated in a 1:2:1 ratio of homozygous resistant/segregating/homozygous susceptible to race 2, 6, and 7, which verifies the monogenic resistance of Tracy to these races (Table 2). The F<sub>3</sub> progenies that were all resistant, segregating, or all susceptible to race 6 had the same reaction to race 7. The F<sub>3</sub> progenies that were all resistant to races 6 and 7 were all resistant, segregating, or all susceptible to race 2. F<sub>3</sub> progenies that were segregating to races 6 and 7 were all resistant, segregating, or all susceptible to race 2, and F<sub>3</sub> progenies that were all susceptible to race 2, and F<sub>3</sub> progenies that were all susceptible to races 6 and 7 were all resistant, segregating, or all susceptible to race 2. This indicates that the reaction of the F<sub>3</sub> progenies to races 6 and 7 was independent of the reaction to race 2, and one of the two genes for resistance in Tracy controls resistance to race 2 and susceptibility to races 6 and 7, whereas the other gene controls resistance to races 6 and 7 and susceptibility to race 2.

The F<sub>2</sub> plants, as tested by their F<sub>3</sub> progenies, segregated in a 7:8:1 ratio of homozygous resistant/segregating/homozygous susceptible to races 1, 3, 4, 5, 8, and 9. The disease reaction of the F<sub>3</sub>

TABLE 1. Segregation of the F<sub>2</sub> population from the soybean cross PI 360952 (susceptible) × Tracy (resistant) to physiologic races 1 through 9 of *Phytophthora megasperma* var. *sojae*

Race	No. of F <sub>2</sub> plants		$\chi^2$ Probability	
	Resistant	Susceptible	3:1 Ratio	15:1 Ratio
1	149	10		0.99-0.98
2	100	30	0.70-0.50	
3	156	6		0.20-0.10
4	174	7		0.20-0.10
5	172	9		0.70-0.50
6	145	44	0.70-0.50	
7	140	32	0.10-0.05	
8	161	8		0.50-0.30
9	165	9		0.70-0.50

progenies verified the F<sub>2</sub> segregation ratio of 15:1 resistant/susceptible, indicating the independent segregation of two dominant genes. Probabilities for  $\chi^2$  goodness of fit all were greater than 0.30, but each race had an apparent excess of resistant F<sub>2</sub> plants and a deficiency of segregating F<sub>2</sub> plants. This undoubtedly resulted from failure (because of the small number of plants inoculated) to find susceptible plants for one race among F<sub>2</sub> plants that were obviously segregating as indicated by their reaction to other races. When these discrepancies were corrected, all F<sub>2</sub> plants reacted the same to races 1, 3, 4, 5, 8, and 9, and the fit to a 7:8:1 ratio of resistant/segregating/susceptible was nearly perfect (43 resistant, 51 segregating, 6 susceptible with a  $\chi^2$  probability of 0.95–0.98).

## DISCUSSION

The parentage of the cultivar Tracy is D61-618 × D60-9647. D61-618 was from Hill × PI 171442 and was known to be resistant to races 1 and 2. Hill is susceptible to all races (2), so any resistance of D61-618 apparently derived from PI 171442, which is one of the differential cultivars used to identify the nine physiologic races of

TABLE 2. Disease reaction of F<sub>3</sub> progenies from F<sub>2</sub> plants of the soybean cross PI 360952 (susceptible) × Tracy (resistant) to physiologic races 1 through 9 of *Phytophthora megasperma* var. *sojae*

Race	No. of F <sub>2</sub> plants			$\chi^2$ Probability	
	Resistant	Segregating	Susceptible	1:2:1	7:8:1
1	48	46	6	0.20–0.10	0.70–0.50
2	33	49	18		0.70–0.50
3	48	46	6		0.50–0.30
4	50	44	6	0.50–0.30	0.50–0.30
5	49	45	6		0.50–0.30
6	22	56	22	0.50–0.30	
7	22	56	22	0.50–0.30	
8	49	45	6		0.50–0.30
9	49	45	6		0.50–0.30

TABLE 3. Expected and observed genotypes of 100 F<sub>2</sub> plants from the cross PI 360952 (susceptible) × Tracy (resistant) based on the disease reaction of their F<sub>3</sub> progenies to physiologic races 1 through 9 of *Phytophthora megasperma* var. *sojae*

	Expected	Observed	$\chi^2$
$Rps_1^b Rps_1^b Rps_3 Rps_3$	6.25	10	2.2500
$Rps_1^b Rps_1^b Rps_3 rps_3$	12.5	9	0.7200
$Rps_1^b Rps_1^b rps_3 rps_3$	6.25	3	1.6900
$Rps_1^b rps_1^b Rps_3 Rps_3$	12.5	16	0.9800
$Rps_1^b rps_1^b Rps_3 rps_3$	25.0	30	1.0000
$Rps_1^b rps_1^b rps_3 rps_3$	12.5	10	0.5000
$rps_1^b rps_1^b Rps_3 Rps_3$	6.25	5	0.2500
$rps_1^b rps_1^b Rps_3 rps_3$	12.5	11	0.3600
$rps_1^b rps_1^b rps_3 rps_3$	6.25	6	0.0100
	Total	7.7600	
		$P = 0.30-0.20$	

*P. megasperma* var. *sojae* and is resistant to all but races 6 and 7 (3). This reaction was reported for PI 86972-1 and ascribed to the gene  $Rps_3$  (4,5). It appears probable that Tracy acquired the gene  $Rps_3$  from PI 171442.

The other parent of Tracy, D60-9647, is resistant to all but race 2. This reaction was reported for PI 84637 and attributed to the gene  $Rps_1^b$  (4,5). Unpublished preliminary data indicate that the differential cultivar Sanga, D60-9647, and PI 84637 have the same dominant gene for resistance,  $Rps_1^b$ . This would indicate that the genotype of Tracy is  $Rps_1^b Rps_1^b Rps_3 Rps_3$ . The data presented in Tables 1 and 2 fully substantiate the independent segregation of two dominant genes, one of which controls resistance to all but race 2, and the other controls resistance to all races except 6 and 7. These reactions are expected from  $Rps_1^b$  and  $Rps_3$ , respectively. The disease reaction of the 100 F<sub>2</sub> plants of the cross PI 360952 × Tracy to all nine physiologic races, as tested by their F<sub>3</sub> progenies, was in good agreement with the expected genotypic segregation (Table 3).

Kilen (2) reported that crosses of Tracy and susceptible soybean lines produced progeny with segregation indicating two major genes when inoculated with race 1. The F<sub>2</sub> progeny from crosses of Picket 71 ( $Rps_1^c Rps_1^c$ ) and Davis ( $Rps_2 Rps_2$ ) segregated in a ratio of about 63 resistant and 1 susceptible, indicating that the two major genes for resistance in Tracy occupy loci different from  $Rps_1^c$  and  $Rps_2$ . The 63:1 segregation in the Davis × Tracy cross is compatible with our suggestion that Tracy has the genotype  $Rps_1^b Rps_1^b Rps_3 Rps_3$ . A 63:1 segregation would not be expected, however, in the cross of Picket 71 ( $Rps_1^c Rps_1^c$ ) with Tracy ( $Rps_1^b Rps_1^b Rps_3 Rps_3$ ).

The results have had practical application. We selected F<sub>2</sub> lines adapted to the latitude of Indiana with resistance to all nine races from populations with Tracy parentage by testing with only race 6 or 7 and race 2. In practice, we inoculate with race 6 or 7 first to determine the presence of the  $Rps_1^b$  gene that gives resistance to races 6 and 7. Race 2 has been reported only from Mississippi, so cultivars with the genotype  $Rps_1^b Rps_1^b rps_3 rps_3$  give complete resistance to the disease in the Midwest.

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