

Inheritance and Linkage of the *Rps7* Gene for Resistance to Phytophthora Rot of Soybean

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ABSTRACT

Anderson, T. R., and Buzzell, R. I. 1992. Inheritance and linkage of the *Rps7* gene for resistance to Phytophthora rot of soybean. *Plant Dis.* 76:958-959.

An *Rps* allele in the Harosoy cultivar of soybean (*Glycine max*) for resistance to races 16, 18, and 19 of *Phytophthora megasperma* f. sp. *glycinea* was shown to be at a new locus, designated *Rps7*, which is linked 12.5 ± 2.7 map units from *Rps1* in Linkage Group 10.

Preliminary results indicated that the Harosoy cultivar of soybean (*Glycine max* L.) has an allele that provides resistance to races 12, 16, 18, and 19 of *Phytophthora megasperma* Drechs. f. sp. *glycinea* T. Kuan & D. C. Erwin (6). The allele was given the temporary designation *Rps?* (Harosoy). Anderson and Buzzell (1) reported the possibility of a linkage between *Rps?* (Harosoy) and *Rps1* after comparing 10 backcross-derived *Rps1* cultivars with their recurrent *rps1* cultivars.

The purpose of this study was to determine the inheritance and linkage of *Rps?* (Harosoy). Because *Rps?* gives a resistant reaction to isolates of *P. m. glycinea* races 16, 18, and 19, the reaction for other *Rps* genes to these races was tested in the absence of *Rps?* (Harosoy) to verify published reactions (7) and to assist completion of a two-way table of interactions of known races of *P. m. glycinea* and *Rps* genes. *P. m. glycinea* race 12, which gives an incompatible reaction with *Rps?* (Harosoy), was not used in this study, because it cannot be differentiated from race 19 at present (2,3).

MATERIALS AND METHODS

F₁ and F₂ soybean plants were obtained from the cross of HARO 13 (*Rps1-b Rps1-b rps? rps?*) with Harosoy 63 (*Rps1-a Rps1-a Rps? Rps?*). HARO 13, an *Rps* isolate of Harosoy (4), was used because of its susceptibility to races 16, 18, and 19 of *P. m. glycinea*.

Each of 135 F₂ plants were progeny-tested by inoculating F₃ seedlings with isolates of race 2 and race 19. Expected genotypes and reactions to inoculation (without distinguishing homozygous and heterozygous F₂'s) are presented in Table 1.

The cross of HARO 16 (*Rps1-d Rps1-d rps? rps?*) × HARO 15XX (*Rps1-k Rps1-k Rps? Rps?*) was also used to characterize the linkage of *Rps1* and *Rps?*. In addition to the reactions reported by Buzzell and Anderson (3) for *P. m. glycinea* race 17, the genotype of 43 F₂ plants was determined by inoculating F₄ seedlings with an isolate of race 19. Expected genotypes and reactions to inoculation (without distinguishing homozygous and heterozygous F₂'s) are presented in Table 2.

With the *Rps* alleles in coupling phase (*Rps1-a* with *Rps?* and *Rps1-k* with *Rps?*) for both of the above crosses, the first and fourth genotypes listed in each cross (Tables 1 and 2) are parental types, and the second and third classes are recombinants.

Seedlings were inoculated with isolates of *P. m. glycinea* by the wounded hypocotyl method and covered with plastic bags for 24–48 hr following inoculation (3). Progeny or lines were considered susceptible if 70% or more inoculated seedlings were killed and resistant if 70% or more survived. Twelve to 18 seedlings were inoculated per race for each F₂ plant, but if results were not conclusive additional seedlings were inoculated. Ten cultivars (Altona, Corsoy 79, Harosoy, Harosoy 63, Kingwa, Mack, Mukden, Sanga, Williams, and Williams 82), three plant introductions (PI 91 160, PI 103 091, and PI 171 442), four lines (OX682, PRX145-87, PRX146-36, and PRX146-

47), and 18 *Rps* isolines of Harosoy (HARO (1-7)1, HARO 12, HARO 13, HARO 1372, HARO 15, HARO 1572, HARO 16, HARO 3272, HARO 5272, and HARO 6272) and Williams (L62-904, L70-6494, L75-3735, L75-6141, L76-1988, L77-1863, L85-2352, and L85-3059) were inoculated with isolates of races 16, 18, and 19. Nineteen *Rps6 Rps6* lines obtained from the cross of Altona (*Rps6*) × Kentland (*rps6 rps6 rps? rps?*) and 14 lines of the genotype *Rps4 Rps4 Rps1-c Rps1-c* obtained from crosses where *Rps4* had been derived from PI 86 050 were tested with isolates of races 16, 18, and 19. All isolates of *P. m. glycinea* used in this study were originally isolated in Mississippi by B. L. Keeling and maintained in culture at the Harrow research station during the past several years.

RESULTS AND DISCUSSION

The individual alleles at the *Rps1* and *Rps?* loci segregated three resistant to one susceptible as expected when inoculated with *P. m. glycinea* races 2, 17, and 19 (Table 3). Linkage tests for pooled data indicated that *Rps?* is linked with *Rps1* at 12.5 ± 2.7 map units (Table 4). Since *Rps2*, *Rps3*, *Rps4*, *Rps5*, and *Rps6* are not linked with *Rps1* (5), then *Rps?* must be at a different locus. The *Rps?/rps?* alleles are assigned the gene symbols *Rps7/rps7*. Since *Rps7* is linked with *Rps1*, *Rps7* must be in Linkage Group 10 (5).

Results indicate that with *Rps1-a*, *Rps1-b*, *Rps1-c*, *Rps1-d*, *Rps1-k*, *Rps3-a*, *Rps3-b*, and *Rps5* the presence or absence of *Rps7* can be determined from reactions with *P. m. glycinea* races 16, 18, and 19 (Table 5). *Rps2*, *Rps4*, and *Rps6* each give a resistant reaction to each of the *P. m. glycinea* races 16, 18, and 19; thus, pedigree information and/or progeny tests are needed to determine whether *Rps7* is present. PRX145-87 (*Rps3-c*) gave a resistant reaction with each of the *P. m. glycinea* races 16, 18, and 19, but material was not available to test whether *Rps7* was present or absent.

With the assignment of gene symbol

Accepted for publication 13 April 1992.

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Table 1. Expected F₂ genotypes of HARO 13 × HAROSOY 63 and reactions from inoculation with isolates of *Phytophthora megasperma* f. sp. *glycinea* races 2 and 19

F ₂ genotypes ^a		Race 2	Race 19
<i>Rps1-a</i> _	<i>Rps?</i> _	Resistant	Resistant
<i>Rps1-b Rps1-b</i>	<i>Rps?</i> _	Susceptible	Resistant
<i>Rps1-a</i> _	<i>rps? rps?</i>	Resistant	Susceptible
<i>Rps1-b Rps1-b</i>	<i>rps? rps?</i>	Susceptible	Susceptible

^a Blank indicates homozygous and heterozygous genotypes combined.

Table 3. Segregation of *Rps* alleles in two soybean crosses inoculated with *Phytophthora megasperma* f. sp. *glycinea*

	Resistant	Susceptible	Expected ratio	P
HARO 13 × Harosoy 63				
Segregation	<i>Rps1-a</i> _	<i>Rps1-b Rps1-b</i>		
Race 2	99	36	3:1	0.8-0.7
Segregation	<i>Rps?</i> _	<i>rps? rps?</i>		
Race 19	100	35	3:1	0.9-0.8
HARO 16 × HARO 15XX				
Segregation	<i>Rps1-k</i> _	<i>Rps1-d Rps1-d</i>		
Race 17 ^a	36	7	3:1	0.3-0.2
Segregation	<i>Rps?</i> _	<i>rps? rps?</i>		
Race 19	32	11	3:1	0.95-0.90

^a Results from Buzzell and Anderson (3). Blank indicates homozygous and heterozygous genotypes combined.

Rps7, Harosoy *Rps* isolines HARO 13XX, HARO 15XX, HARO 32XX, HARO 52XX, and HARO 62XX are now designated HARO 1372, HARO 1572, HARO 3272, HARO 5272, and HARO 6272, respectively, to indicate the presence of *Rps7*. HARO 12 and HARO 15 were obtained as recombinant lines in this study. HARO (1-7) is a Harosoy isolate (Table 5) having *rps* at all seven known loci (*unpublished*).

ACKNOWLEDGMENTS

R. D. Walker, L. J. Boose, and C. P. Meharg provided technical assistance. The Soybean Genetics Committee approved the assignment of the gene symbol. K. L. Athow provided seed of the PRX lines; R. L. Bernard and C. D. Nickell provided seed of the L lines.

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Table 2. Expected F₂ genotypes of HARO 16 × HARO 15XX and reactions from inoculation with isolates of *Phytophthora megasperma* f. sp. *glycinea* races 17 and 19

F ₂ genotypes ^a		Race 17	Race 19
<i>Rps1-k</i> _	<i>Rps?</i> _	Resistant	Resistant
<i>Rps1-d Rps1-d</i>	<i>Rps?</i> _	Susceptible	Resistant
<i>Rps1-k</i> _	<i>rps? rps?</i>	Resistant	Susceptible
<i>Rps1-d Rps1-d</i>	<i>rps? rps?</i>	Susceptible	Susceptible

^a Blank indicates homozygous and heterozygous genotypes combined.

Table 4. Linkage tests for *Rps?* in two soybean crosses inoculated with *Phytophthora megasperma* f. sp. *glycinea*

	Class				Sum	R ^a SE
	RR	RS	SR	SS		
HARO 13 (<i>Rps1-b Rps1-b rps? rps?</i>) × Harosoy 63 (<i>Rps1-a Rps1-a Rps? Rps?</i>)						
Race	2 19	2 19	2 19	2 19		
F ₂	92	7	8	28	135	11.5 ± 3.0
HARO 16 (<i>Rps1-d Rps1-d rps? rps?</i>) × HARO 15XX (<i>Rps1-k Rps1-k Rps? Rps?</i>)						
Race	17 19	17 19	17 19	17 19		
F ₂	31	5	1	6	43	12.7 ± 5.5
Pooled						
F ₂	123	12	9	34	178	12.5 ± 2.7

^a Recombination map units with standard error.

Table 5. Soybean *Rps* reactions from inoculations with *Phytophthora megasperma* f. sp. *glycinea* races 16, 18, and 19

Lines tested	Genes present		Race		
	1st	2nd	16	18	19
HARO (1-7) ¹ , ^a Williams ^b	<i>rps</i> ^c	<i>rps7</i>	S ^d	S	S
Harosoy (HARO 72) ^a	<i>rps</i> ^c	<i>Rps7</i>	R ^c	R	R
Mukden, HARO 12 ^a , L75-6141 ^b	<i>Rps1-a</i>	<i>rps7</i>	R	R	S
Harosoy 63 (HARO 1272) ^a	<i>Rps1-a</i>	<i>Rps7</i>	R	R	R
Sanga, HARO 13, ^a L77-1863 ^b	<i>Rps1-b</i>	<i>rps7</i>	S	R	S
HARO 1372 ^a	<i>Rps1-b</i>	<i>Rps7</i>	R	R	R
Mack, OX682, Corsoy 79, L75-3735 ^b	<i>Rps1-c</i>	<i>rps7</i>	S	S	S
PI 103 091, HARO 16 (OX642) ^a	<i>Rps1-d</i>	<i>rps7</i>	R	R	S
Kingwa, HARO 15, ^a Williams 82 ^b	<i>Rps1-k</i>	<i>rps7</i>	S	R	S
HARO 1572 ^a	<i>Rps1-k</i>	<i>Rps7</i>	R	R	R
L76-1988 ^b	<i>Rps2</i>	<i>rps7</i>	R	R	R
L70-6494 ^a	<i>Rps2</i>	<i>Rps7</i>	R	R	R
PI 171 442	<i>Rps3</i>	<i>rps7</i>	R	R	S
HARO 3272 ^a	<i>Rps3</i>	<i>Rps7</i>	R	R	R
PRX146-36, PRX146-47	<i>Rps3-b</i>	<i>rps7</i>	S	S	S
PRX145-87	<i>Rps3-c</i>	?	R	R	R
L85-2352, ^b 14 <i>Rps4</i> lines, PI 86 050	<i>Rps4</i>	<i>rps7</i>	R	R	R
PI 91 160 (T240), L85-3059 ^b	<i>Rps5</i>	<i>rps7</i>	R	R ^f	S
L62-904, ^a HARO 5272 ^a	<i>Rps5</i>	<i>Rps7</i>	R	R	R
Altona, 19 lines Altona × Kentland	<i>Rps6</i>	<i>rps7</i>	R	R	R
HARO 6272 ^a	<i>Rps6</i>	<i>Rps7</i>	R	R	R

^a Harosoy *Rps* isolate.

^b Williams *Rps* isolate.

^c *rps* at the *Rps1*, *Rps2*, *Rps3*, *Rps4*, *Rps5*, and *Rps6* loci.

^d S = Susceptible (70% or more of the seedlings killed).

^e R = Resistant (70% or more of the seedlings lived).

^f Results for PI 91 160 were variable with race 18.

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