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GENETIC SYSTEM FOR THE REACTION OF *Phaseolus vulgaris* TO THE BA-2 (ALPHA) RACE OF *Colletotrichum lindemuthianum*

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ABSTRACT

Seven cultivars of the common bean (*Phaseolus vulgaris* L.) were evaluated for their reaction to the BA-2 (alpha) race of anthracnose (*Colletotrichum lindemuthianum* [Sacc. & Magn.] Scrib.). Parental, F_1 and F_2 plants from 20 crosses involving resistant and susceptible cultivars were inoculated with this fungus. Genetic resistance to the BA-2 race in the seven bean cultivars can be accounted for by two dominant genes, *Are* and *A*, which behave as duplicate factor loci. In addition, interaction of the dominant loci *X* and *Y*, belonging to a complementary factor system, confers a resistant reaction to the BA-2 race.

INTRODUCTION

Anthracnose of common beans is a seed-borne disease caused by the fungus *Colletotrichum lindemuthianum* (Sacc. & Magn.) Scrib. It can cause serious losses where (or when) humid weather with comparatively low temperature prevails. Chemical treatments, use of pathogen-free seeds, and crop rotation have been indicated as measures to control the disease (Chaves, 1980; Vieira, 1983). Under Brazilian conditions, however, breeding and selection of resistant cultivars is the most appropriate control measure, since the majority of bean growers are small farmers who employ simple production technology and associated cropping (Vieira, 1983).

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The development of resistant cultivars, however, is complicated by the existence of several strains or physiological races of the bean anthracnose organism (Oliveira *et al.*, 1973; Oliari *et al.*, 1973; Pio-Ribeiro and Chaves, 1975; Paradela Filho and Pompeu, 1975; Paradela Filho *et al.*, 1981; Menezes, 1985). Sources of resistance to the different races have been sought. Mastenbroek (1960) found that Cornell 49-242, a Venezuelan black bean, carries a dominant gene (*Are*), which confers resistance to the races alpha, beta, gama, delta, epsilon, and lambda (Chaves, 1980). Cornell 49-242 has been used in Brazil in programs for breeding anthracnose-resistant cultivars.

Andrus and Wade (1942), Cardenas *et al.* (1964), and Muhalet *et al.* (1981) have found that genetic control of resistance to the different races of anthracnose is conferred by duplicate and complementary factors, and by an allelomorphic series. Oliari *et al.* (1973) and Pio-Ribeiro and Chaves (1975), using Michelite, Dark Red Kidney, Perry Marrow, Emerson 847, *Phaseolus aborigineus* 283, and Costa Rica 1031 as differential cultivars, were able to identify ten anthracnose races, which they designated BA-1, BA-2, BA-3, —BA-10. BA-2 belongs to the alpha group, which appears to be the most common group in Brazil.

The present study was conducted to investigate the inheritance of resistance to the BA-2 race in crosses involving the differential cultivars and Cornell 49-242, to provide useful information for breeding programs as well as information about the genotypes of the differential cultivars.

MATERIAL AND METHODS

A culture of the BA-2 race of anthracnose was obtained from the Department of Plant Pathology, Federal University of Viçosa, where a monosporic culture of the pathogen has been maintained on Mathur's media at 5°C. Pathogenicity has been tested on the differential cultivars at frequent intervals.

The seven parents were crossed in all 21 possible combinations. F_1 seeds from 20 crosses were obtained and used in the study, since the cross Emerson 847 x Dark Red Kidney yielded a very small number of hybrid seeds. F_1 seeds from each cross were grown to produce the F_2 seeds, while the rest were used later to test the F_1 disease reaction.

Parental, F_1 and F_2 generations were grown in pots 7 cm diameter and 12 cm high, filled with soil previously mixed with mineral fertilizers and organic matter. Fifteen days after planting, at the first trifoliolated leaf stage, the resulting seedlings were inoculated with a suspension preparation of the culture inoculated on bean pods partially immersed in potato dextrose agar media kept at 22°C. Inoculation was made with a hair brush, previously wetted in the appropriate spore suspension (adjusted to 2×10^6 spores/ml with a hemacytometer). Inoculated plants were immediately placed

in a mist chamber maintained at near 100% relative humidity at 18-22°C for a period of 4 days. After this incubation period, they were transferred to a greenhouse where they remained until the disease reaction was scored.

Disease reactions were assessed 8 days after inoculation. Plants with no disease symptoms or with a few small isolated lesions on the mid or secondary veins of the leaf were considered resistant. The observed phenotypic ratios of resistant (R) to susceptible (S) plants were compared with theoretical ratios using the chi-square test.

RESULTS AND DISCUSSION

In the R x R crosses, with the exception of Perry Marrow x *P. aborigineus* 283, the F_2 segregated for susceptible and resistant plants (Table I). When Cornell 49-242 was included in the crosses, the resistance was conferred by the *Are* gene. According to Cardenas *et al.* (1964), Emerson 847 and Dark Red Kidney are resistant to the alpha race because they carry the dominant gene *A*. In the cross Emerson 847 x Cornell 49-242 a F_2 segregation ratio of 15R:1S was obtained, indicating the presence of duplicated loci (*Are* and *A*) conferring resistance to the BA-2 race when either one or both genes are in the dominant condition.

When the resistant sources Perry Marrow and *P. aborigineus* 283 were crossed with either Cornell 49-242 or Emerson 847, a F_2 segregation ratio of 57R:7S was obtained. This pattern of segregation can be explained by assuming independent transmission of genes at 4 loci, 2 of which, *Are* and *A*, behave as duplicate factors and the other two, *X* and *Y*, as complementary factors (Table II). F_2 plants from the cross Perry Marrow x *P. aborigineus* 283 were resistant, which is consistent with the four loci hypothesis.

The 15R:1S segregation ratio in the cross Dark Red Kidney with either Perry Marrow or *P. aborigineus* 283 indicated that two dominant genes for resistance were involved. One of them is *A*, transmitted from Dark Red Kidney. As the other two cultivars are resistant due to the complementary factors *X* and *Y*, the results indicate that Dark Red Kidney also carries one of these genes (Table II).

In crosses R x S, the F_2 segregation ratio was 3R:1S. In five crosses the probability of the expected ratio was very low, because many F_2 plants were difficult to classify in relation to disease reaction. However, Cardenas *et al.* (1964) obtained a 3R:1S segregation ratio in the F_2 of the Dark Red Kidney x Michelite and Emerson 847 x Michelite, when inoculated with the alpha race, which is consistent with the proposed genotypes (Table II). To be in accordance with the four loci hypothesis, it is necessary to admit that the susceptible parents, Michelite and Costa Rica 1031, carry the same complementary factor transmitted by Dark Red Kidney (Table II).

Muhalet *et al.* (1981) and the results of this study with the BA-2 (alpha) race demonstrate the complexity of the genetic system for the reaction of common

Table I - Parental, F_1 and F_2 reactions and expected ratios of resistant (R) and susceptible (S) to the BA-2 (alpha) race of anthracnose.

Cross	Parents	F_1	F_2			
			No. of plants		Expected ratio	Probability
			R	S		
Emerson 847 x Cornell 49-242	R x R	R	239	19	15:1	.50 - .70
Perry Marrow x Cornell 49-242	R x R	R	212	27	57:1	.90 - .95
Dark Red Kiney x Cornell 49-242	R x R	R	181	31	15:1	<. 001
P. aborigineus 283 x Cornell 49-242	R x R	R	82	10	57:1	.80 - .90
Perry Marrow x *P. aborigineus* 283	R x R	R	–	–	–	–
Emerson 847 x *P. aborigineus* 283	R x R	R	145	15	57:7	.30 - .50
Dark Red Kidney x *P. aborigineus* 283	R x R	R	200	14	15:1	.90 - .95
Perry Marrow x Dark Red Kidney	R x R	R	194	14	15:1	.80 - .90
Perry Marrow x Emerson 847	R x R	R	175	32	57:7	.02 - .05
Cornell 49-242 x Costa Rica 1031	R x S	R	153	97	3:1	<. 001
P. aborigineus 283 x Costa Rica 1031	R x S	R	91	105	3:1	<. 001
Perry Marrow x Costa Rica 1031	R x S	R	153	53	3:1	.80 - .90
Dark Red Kidney x Costa Rica 1031	R x S	R	144	64	3:1	.05 - .10
Emerson 847 x Costa Rica 1031	R x S	R	101	25	3:1	.20 - .30
Dark Red Kidney x Michelite	R x S	R	127	87	3:1	<. 001
Perry Marrow x Michelite	R x S	R	155	89	3:1	<. 001
Emerson 847 x Michelite	R x S	R	152	82	3:1	<. 001
P. aborigineus 283 x Michelite	R x S	R	150	45	3:1	.50 - .70
Cornell 49-242 x Michelite	R x S	R	186	70	3:1	.30 - .50
Michelite x Costa Rica 1031	S x S	S	–	–	–	–

beans to anthracnose races. According to Muhalet *et al.* (1981), resistance to the beta race depends on genes at four loci, two of which, *Are* and *B*, behave as duplicate factors and the other two, *C* and *D*, as complementary factors. In addition, there is a system of multiple alleles at the *B* locus: B_1 and B_3 confer susceptibility while B_2 confers resistance. Resistance to the gamma race, according to the same authors, depends on the dominant gene *Are*, and on the dominant alleles at either one of two other independent loci, *G* and *H*. In addition, two contemporary factor systems, *I-J* and *K-L*, operate, and either can produce a resistance reaction by interaction with the dominant alleles. Resistance to the delta race, according to Muhalet *et al.* (1981),

Table II - Proposed genotypes of 7 cultivars of beans based on their reactions to infection by the BA-2 (alpha) race of anthracnose.

Cultivar	Duplicate factors	Complementary factors	Reaction
Michelite	*areare aa*	*xx YY*	S
Dark Red Kidney	*areare AA*	*xx YY*	R
Perry Marrow	*areare aa*	*XX YY*	R
Emerson 847	*areare AA*	*xx yy*	R
P. aborigineus 283	*areare aa*	*XX YY*	R
Costa Rica 1031	*areare aa*	*xx YY*	S
Cornell 49-242	*AreAre aa*	*xx yy*	R

depends on the dominant genes at the *Are* and *M* loci; in addition, interaction of the dominant loci *N* and *P*, belonging to a complementary factor system, also confers a resistance reaction.

The number of genes conferring resistance to any of these anthracnose races is limited. The development of resistant cultivars can, therefore, be accomplished by a simple back-crossing procedure. However, one should utilize the dominant gene *Are*, because it confers resistance to the races alpha, beta, gamma, delta, epsilon, and lambda. Race shift is common at the several bean production regions of Brazil, and only the dominant gene *Are* can offer protection against that possibility. However, if the kappa race appears, other genes for resistance should be sought, since *Are* does not give protection against it (Vieira, 1983). Kappa race has already been encountered in Brazil (Menezes, 1985).

RESUMO

Foram avaliadas as reações de sete cultivares de feijão (*Phaseolus vulgaris* L.) à raça BA-2 (alfa) da antracnose (*Colletotrichum lindemuthianum* [Sacc. & Magn.] Scrib.). Plantas das gerações parental, F_1 e F_2, provenientes de 20 cruzamentos envolvendo cultivares resistentes e suscetíveis, foram inoculadas com a raça. A resistência genética à raça BA-2, nos sete cultivares de feijão, pode ser explicada por dois genes dominantes, *Are* and *A*, que se comportam como fatores duplicados. Ademais, a resistência também é conferida pela interação dos genes dominantes *X* e *Y*, que atuam como fatores complementares.

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