Inheritance of Adult Plant Resistance to Crown Rust in an Accession of *Avena sterilis*

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ABSTRACT

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An accession of *Avena sterilis*, Canadian Avena (CAV) accession 1387, which originated from Israel, was susceptible in the seedling stage, but resistant in the adult plant stage to six races of *Puccinia coronata*. Crosses of resistant derivatives of CAV1387 with the susceptible *A. sativa* lines RL3069 or Sun II resulted in F_2 segregation ratios of 1 resistant:2 moderately resistant:1 susceptible plants. It was concluded that the adult plant resistance in CAV1387 was conferred by a single partially dominant gene, designated as *Pc*-69. This gene confers effective field resistance to the races of *P. coronata* that occur in western Canada.

Additional key words: genetics of crown rust resistance, post-seedling resistance.

Accessions of *Avena sterilis* L. collected from the Middle-East and North Africa have provided many genes which confer resistance to the crown rust fungus, *Puccinia coronata* Cda., beginning in the seedling plant stage (5,11,18). Resistance which is effective only in the adult plant stage has also been reported to occur in *A. sterilis* (5,17), but there is no information on its mode of inheritance. Adult plant resistance is also a component of resistance to *P. coronata* in some cultivars of *A. sativa* L. (3,7,10,14). The cultivar Victoria contained two factors, Vc_1 and Vc_3, for adult plant resistance (15), which have been designated as genes *Pc*-27 and *Pc*-28, respectively (11). Adult plant resistance was also found in cultivars Santa Fe and Ukraine (16), but it is not known if it is the same as that in Victoria.

This paper describes the inheritance of adult plant resistance in one accession of *A. sterilis*.

MATERIALS AND METHODS

Test races of *P. coronata*. The virulence characteristics of the six races of *P. coronata* used in this study are shown in Table 1. The races are designated by Winnipeg accession (CR) numbers, and the equivalent "standard" race numbers (12) are included for comparison.

The *A. sterilis* parent. Accessions of *A. sterilis* were initially screened with races CR12 and CR37 in the seedling stage and with CR25 in the adult plant stage. All adult plant tests were carried out by inoculating and evaluating the flag leaves for infection type (13). The plants were grown in a greenhouse with an 18-hr photoperiod at a mean temperature of 20 C. One accession, Canadian Avena (CAV) accession 1387 (which originated from Israel), was susceptible in the seedling stage and resistant in the adult stage. In subsequent tests with races CR12, CR37, CR25, CR20, CR32, and CR46 in the seedling and adult plant stages, the plants were uniformly susceptible in the seedling stage and resistant in the adult plant stage to all six races. The resistance was expressed as a ;2 (13) infection type. Accession CAV1387 was then used in crosses to study the inheritance of the adult plant resistance.

Crossing and analysis of progeny. The *A. sterilis* accession CAV1387 was used as the female parent in an initial cross with the cultivar Fraser, which is susceptible to the known races of *P. coronata* (infection type 4–4 on the seedling and flag leaves). The F_1 plants were backcrossed to 'Fraser' to produce 93 backcross families. The BC_1F_2 progeny were to be used to analyze the mode of inheritance of the resistance in CAV1387, but due to extensive leaf necrosis the populations were too small for genetic analysis. Then eight resistant plants (infection type ;2+), each from a different backcross family from the above test were selected and selfed to the F_4 generation. In each generation, plants were tested for resistance in both the seedling and adult stages to obtain plants that were homozygous resistant. Selected resistant F_4 plants were then used for further crossing and for tests for resistance in the field.

The CAV1387/Frazer BC_1F_4 plants were crossed using the line RL3069 (Rodney 0*2/CI9139//2* Fraser) as the male parent. The line RL3069 is susceptible (infection type 4–4 on the seedling and flag leaves) to the known races of *P. coronata*, but carries gene *Pg*-a (synonymous with gene *Pg*-12+) for resistance to *P. graminis* f. sp. *avenae* (6). The line RL3069 was used to enable the isolation of *P. coronata* from *P. graminis* f. sp. *avenae*.

A further cross using one of the eight above parental lines was made using the cultivar Sun II as the male parent. Cultivar Sun II reacts with infection type 4 to the known races of *P. coronata* in both the seedling and flag leaf stages.

In all tests, the F_2 progeny from the above crosses were grown in a growth cabinet at 18 C and an 18-hr photoperiod. The flag leaves were inoculated with fresh urediospores of race CR46 of *P. coronata*, the plants were incubated overnight at 100% relative humidity, then continued growth in the growth cabinet as above. The infection types were scored 14 days after inoculation.

The chi-square test was applied to determine goodness-of-fit to theoretical segregation ratios. The original CAV1387 parent and the recurrent parents were included as controls in all tests.

TABLE 1. Key to the isolates of *Puccinia coronata* used to screen for adult plant resistance in *Avena sterilis* and to test segregating populations of *A. sterilis* accession CAV1387/*A. sativa* crosses

Winnipeg accession no.	Standard race no.[a]	Effective/ineffective host resistance (*Pc*)[b] genes
CR12	264	38,39,45,46,47,48,50,54,55,56,62,63/35,40
CR20	295	35,38,39,40,45,46,47,48,54,55,56,62,63/50
CR25	305	35,38,50,56,62,63/39,40,45,46,47,58,54,55
CR32	210	35,38,39,40,45,46,47,48,50,54,55,56,62,63/
CR37	239	35,38,39,40,45,46,47,48,50,54,55,62,63/56
CR46	326	35,38,39,40,45,46,47,48,50,54,55,56,62,63/

[a] Simons and Michel (12).
[b] The *Pc*-genes in this table, all derived from *A. sterilis* (Simons, et al 11), are used to identify the Winnipeg (CR) isolates of *P. coronata*.

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TABLE 2. Segregation for resistance to race CR46 of *Puccinia coronata* of F_2 populations from crosses between *Avena sterilis* accession CAV1387-derived resistant lines (CAV1387/*A. sativa* Fraser BC_1F_4) and the susceptible *A. sativa* line RL3069 or Sun II

Crosses	Infection type and no. of plants ;12	3–3	3+4	Ratio	*P*
CAV1387-derivatives/RL3069[a]	205	437	235	1:2:1	0.30–0.50
CAV1387-derivatives/Sun II[a]	32	54	29	1:2:1	0.70–0.80

[a]The results involving RL3069 are summarized from crosses with eight CAV1387/Fraser derivatives and those involving cultivar Sun II are from one of the above derivatives.

RESULTS AND DISCUSSION

The progeny from the crosses of all eight resistant lines (derived from CAV1387/Fraser) with RL3069 segregated similarly, and the results (Table 2) are a summary of all eight crosses. The progeny segregated into three classes in a ratio of 1 resistant (infection types ;12):2 moderately resistant (infection types 3–3):1 susceptible (infection types 3+4) plants ($P = 0.30–0.50$). If the resistant and moderately resistant classes are combined, the resulting segregation was 652 resistant:235 susceptible plants, which is a good fit to a 3:1 segregation ratio ($P = 0.50–0.70$). These results indicate that the resistance is conferred by a single partially dominant gene, with the heterozygous plants accounting for the intermediately resistant infection types.

The cross of one of the resistant parents, which had also been crossed with RL3069, and with cultivar Sun II also resulted in an F_2 segregation ratio of 1 resistant:2 moderately resistant:1 susceptible plants ($P = 0.70–0.80$, Table 2). Combining the resistant and moderately resistant classes resulted in 86 resistant:29 susceptible plants, which is an excellent fit to a 3:1 segregation ratio ($P = 0.90–0.95$). These results confirm those from the RL3069 cross, and it is concluded that the adult plant resistance in CAV1387 is controlled by a single partially dominant gene, which has been designated as *Pc*-69 (M. D. Simons, *personal communication*).

Progeny (F_4) from the original CAV1387/Fraser cross and the subsequent cross with RL3069 were grown in inoculated field nurseries at Glenlea, Manitoba, during two growing seasons. In the field, plants carrying gene *Pc*-69 showed a characteristic ;12 infection type with a small sharply defined area of yellowish-white chlorosis around the pustules. In the field tests, the plants were also subject to the prevailing natural inoculum of *P. coronata*, and no susceptible-type pustules were observed. In greenhouse tests, inoculation with races CR13, 20, 32, 37, and 46 usually produced ;2+ infection types, while CR25 produced the somewhat less resistant 2+3 infection types. Although the complete range of resistance conferred by gene *Pc*-69 is not known, the results to date indicate that it is effective against the prevailing races of *P. coronata* in western Canada, indicating a relatively broad range of resistance.

Adult plant resistance has been an important component of leaf and stem rust resistance in wheat (1,9). The inheritance of this type of resistance may be either simple (2) or complex (4) and tends to be quite durable, although its effectiveness may also be subject to changes in the pathogen population (8,9). The effectiveness of gene *Pc*-69 and its ease of transfer make it a good candidate for combination with other seedling resistance genes to provide an enhanced broadly-based resistance to crown rust.

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