ADDITIONAL RESISTANCE IN *TRITICUM VULGARE* TO *ERYSIPHE GRAMINIS TRITICI*

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Summary

Additional genetic studies have been made of the resistance of four wheat varieties to races *P*, *P*-1, and *T* of *Erysiphe graminis tritici*.

P.I.92378, P.I.181374, and the derived variety Javelin-325 were each shown to possess the Ulka gene Ml_u, while Asosan was shown to possess a sixth gene, Ml_a, not previously detected.

A race of *E. graminis tritici* (race *T*) capable of attacking those varieties carrying the Ml_t gene alone provided supplementary evidence of the genetic constitution of the several experimental varieties.

Four "tester" lines, each with a Federation background, have been produced. They each carry, singly, the genes Ml_t, Ml_s, Ml_u, and Ml_a and should prove particularly useful in physiological race determinations.

I. INTRODUCTION

Genetic studies of the inheritance of resistance of 13 varieties of *Triticum vulgare* Vill. to *Erysiphe graminis tritici* have led to the identification of five genes governing the resistance of such varieties to powdery mildew (Pugsley and Carter 1953; Carter 1954). The five genes were designated Ml_t, Ml_u, Ml_s, Ml_c, and Ml_b, having been detected originally in the varieties Thew, Ulka, Sonora, Chul, and Birdproof respectively.

Mildew resistance studies have been continued over the past six years and a genetic analysis has been made of four additional varieties. The occurrence, in 1960, of a new race of *E. graminis tritici*, characterized by being able to attack those varieties carrying the Ml_t gene alone, at once provided evidence that the resistance of these four varieties was not conditioned by either of the genes Ml_t, Ml_c, Ml_s, or Ml_b. Reference to Table 1 shows that Thew (Ml_t) and Chul-1 (Ml_c) were susceptible and Sonora (Ml_s) and Birdproof (Ml_b) were moderately resistant to the new race.

Studies outlined in this paper were designed to secure evidence on the identity of the genes for resistance in the four varieties P.I.92378, P.I.181374, Javelin-325, and Asosan, all four being resistant to the new race *T*.

II. MATERIALS AND METHODS

Twelve varieties have already been described (Pugsley and Carter 1953). Chul (C.I.2227) used in Carter's (1954) studies, although uniform in its reaction to mildew, was found to be heterogeneous for auricle colour and the selection Chul-1, with red auricles, has been used since 1955.

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Two varieties were selected for mildew resistance from the United States Department of Agriculture world collection of varieties resistant to stem and leaf rust. They are No. 9446 (P.I.92378) from Russia and P.I.181374 from Afghanistan. The varieties C.I.12633 from the United States of America and P.I.170913 from Transvaal are believed to be derivatives of *T. timopheevi* and, although they have not been used in genetic studies, they have remained quite resistant whenever tested for mildew reaction during the past eight years.

The Japanese variety Asosan (C.I.12665) was obtained from the United States Department of Agriculture in 1954. Stevenson and Jones (1953) reported it as being resistant to mildew. Stevenson and Jones also reported Picardie (C.I.12664) from

TABLE 1

REACTION OF WHEAT VARIETIES TO RACES *P*, *P*-1, AND *T* OF E. GRAMINIS TRITICI

R, resistant; S, susceptible; MR, resistant but slight development of mildew on leaf sheath of seedlings

Variety	Race *P*	Race *P*-1	Race *T*	Variety	Race *P*	Race *P*-1	Race *T*
Axminster	R	R	S	Sonora	MR	MR	MR
Converse	R	R	S	Sturgeon	MR	MR	MR
Huron	R	R	S	P.I.92378	R	R	R
Kenya C.6041	R	R	S	P.I.181374	R	R	R
Norka	R	R	S	Javelin-325	R	R	R
Thew	R	R	S	Asosan	R	R	R
Birdproof	R	R	MR	C.I.12633	R	R	R
Normandie	R	R	R	P.I.170913	R	R	R
Ulka	R	R	R	Suwon 92	MR	—	—
Chul-1	S	R	S	Picardie	S	—	—
Indian	MR	MR	MR	Federation	S	S	S

France and Suwon 92 (P.I.157603) from Korea as being resistant to mildew. However, Picardie was found to be susceptible and Suwon 92 to be moderately resistant in 1955 and were not studied further.

Javelin-325 is a resistant selection of a fifth backcross, Javelin being the recurrent parent and Iumillo × *Aegilops squarrosa* the donor parent. The amphiploid donor parent was obtained from Dr. E. P. Baker, University of Sydney, in 1951 who, in turn, had received it from Dr. E. R. Sears of Missouri, U.S.A.

During the period 1955–1959 several mildew resistant varieties were used as donor parents in a backcross programme with the standard mildew susceptible Federation as the recurrent parent. In this way several "tester" varieties have been produced each with a different gene in a common Federation background. Marker genes have been retained as an aid to their ready identification. The following tester lines are now available:

T-Federation (Ml_t gene), Kenya C.6041 × Federation[5]. Marked by the Sr_9 gene for resistance to stem rust.

S-Federation (Ml_s gene), Sonora × Federation[4]. Marked by pubescent chaff.

U-Federation (Ml_u gene), Ulka × Federation[4]. Marked by late maturity.

A-Federation (Ml_a gene), Asosan × Federation[3]. Marked by white chaff and red grain.

The four tester lines together with others that may be produced in the future should prove useful as differentials in race determination studies.

TABLE 2

CLASSIFICATION OF F_2 SEGREGATES FOR THE CROSSES INDICATED WITH RESPECT TO MILDEW REACTIONS

R, resistant; S, susceptible

Cross and Parental Reactions	Resistant	Susceptible	Ratio	Value of P for Ratio Indicated
Race *P*, 1955				
Federation × P.I.92378 (S × R)	50	12	3 : 1	>0·20
Thew × P.I.92378 (R × R)	130	4	15 : 1	>0·10
Federation × P.I.181374 (S × R)	51	12	3 : 1	>0·20
Thew × P.I.181374 (R × R)	127	7	15 : 1	>0·50
Ulka × P.I.181374 (R × R)	74	0	—	—
Race *P*-1, 1956				
Asosan × Federation (R × S)	96	36	3 : 1	>0·50
Asosan × Ulka (R × R)	92	7	15 : 1	>0·70
Asosan × Thew (R × R)	83	7	15 : 1	>0·50
Federation × P.I.92378 (S × R)	117	28	3 : 1	>0·10
Thew × P.I.92378 (R × R)	69	5	15 : 1	>0·80
Race *P*-1, 1959				
A-Federation × Federation (R × S)	73	30	3 : 1	>0·30
T-Federation × Federation (R × S)	86	25	3 : 1	>0·50
U-Federation × Federation (R × S)	82	20	3 : 1	>0·20
U-Federation × A-Federation (R × R)	105	3	15 : 1	>0·10
U-Federation × T-Federation (R × R)	103	6	15 : 1	>0·70
Javelin-325 × Federation (R × S)	69	32	3 : 1	>0·10
Javelin-325 × U-Federation (R × R)	109	0	—	—
Javelin-325 × T-Federation (R × R)	112	6	15 : 1	>0·50
Javelin-325 × A-Federation (R × R)	103	7	15 : 1	>0·95
Javelin-325-Federation × P.I.92378-Federation (R × R)	121	0	—	—

Two tester lines, Javelin-325-Federation and P.I.92378-Federation each with the Ml_u gene were used in addition to the above in several test crosses.

Material was tested as seedlings grown in flats in the greenhouse. The races of mildew used were those which appeared in the greenhouse at the commencement of the growing season each autumn. Races *P* and *P*-1 (Pugsley and Carter 1953) were present during 1955 and 1956–59 respectively, while a distinctively different race (designated *T*) was present in 1960.

III. Experimental Results

The reactions of the standard and experimental varieties to races *P*, *P*-1, and *T* are given in Table 1.

A limited number of segregating F_2 populations were available for testing in 1955 and 1956, the results of which are summarized in Table 2. Tentative conclusions drawn from these experiments were as follows: P.I.92378 possesses a single gene for resistance different from Ml_t carried by Thew. P.I.181374 possesses a single gene for resistance different from Ml_t but which may be identical with Ml_u carried by Ulka. Asosan possesses a single gene for resistance different from Ml_t and Ml_u. This has been designated Ml_a.

Table 3

Classification of F_2 and backcross segregates for the crosses indicated with respect to mildew reactions

R, resistant; S, susceptible

Cross and Parental Reactions	Resistant	Susceptible	Ratio	Value of *P* for Ratio Indicated
Race *T*, 1960				
Federation × A-Federation (S × R)	126	48	3 : 1	>0·30
Javelin-325 × T-Federation (R × S)	62	26	3 : 1	>0·30
Javelin-325 × A-Federation (R × R)	158	18	15 : 1	>0·02
Javelin-325-Federation × U-Federation (R × R)	83	0	—	—
(U-Federation × Javelin-325-Federation)[1] × Federation (R × R)[1] × S	15	0	—	—
Javelin-325-Federation × P.I.92378-Federation (R × R)	88	0	—	—
T-Federation × P.I.92378-Federation (S × R)	59	18	3 : 1	>0·70
T-Federation × U-Federation (S × R)	115	42	3 : 1	>0·50
T-Federation × A-Federation (S × R)	115	35	3 : 1	>0·50
(T-Federation × A-Federation)[1] × Federation (S × R)[1] × S	31	31	1 : 1	>0·99
U-Federation × A-Federation (R × R)	134	8	15 : 1	>0·70
(U-Federation × A-Federation)[1] × Federation (R × R)[1] × S	42	15	3 : 1	>0·80

By 1959 further segregating F_2 populations, including intercrosses between the Federation tester lines, were available, the results of which are also summarized in Table 2.

Confirmatory evidence was secured that T-Federation, U-Federation, and A-Federation carry the genes Ml_t, Ml_u, and Ml_a respectively. The results indicate that Javelin-325 possesses a single gene different from Ml_t and Ml_a but which may be identical with Ml_u of U-Federation. Failure to recover susceptible segregates from the cross P.I.92378-Federation × Javelin-325-Federation supports the view that these two lines carry the common gene Ml_u.

The appearance of the new *T* race of *E. graminis tritici* in 1960 at once screened those varieties carrying the Ml_t gene alone—all proving susceptible (see Table 1). Two varieties, Normandie and Birdproof, previously shown to possess genes Ml_u and Ml_b, respectively, in addition to Ml_t (Pugsley and Carter 1953; Carter 1954), were resistant and moderately resistant to the *T* race.

A distinctly different pattern of behaviour was apparent when segregating populations were exposed to the *T* race, the results being summarized in Table 3. The results of several backcrosses to the susceptible Federation supported the data obtained from F_2 populations.

It should be emphasized that throughout this work the recorded results refer to the reactions of wheat seedlings to mildew. The likelihood that some type of

TABLE 4

GENES CONFERRING RESISTANCE OF WHEAT VARIETIES TO EACH OF THE THREE RACES

Variety	Genes Conferring Resistance		
	Race *P*	Race *P*-1	Race *T*
Thew	Ml_t	Ml_t	—
Sonora	Ml_s*	Ml_s*	Ml_s*
Ulka	Ml_u	Ml_u	Ml_u
Asosan	Ml_a	Ml_a	Ml_a
Normandie	Ml_t Ml_u	Ml_t Ml_u	Ml_u
Birdproof	Ml_b* Ml_t	Ml_b* Ml_t	Ml_b*
Chul-1	—	Ml_c	—

* Moderate resistance only.

mature plant resistance may be operative should not be overlooked. Such appeared to be the case within the group of varieties carrying the single Ml_t gene, where Thew, Huron, and Converse were less susceptible at the heading stage compared with Norka and T-Federation.

The resistance associated with Ml_a is not completely dominant. This was observed for race *P*-1 in 1956 and 1959 and, later, for race *T* in 1960. Heterozygous plants frequently, but not invariably, develop a little mildew on the leaf sheath. Heterozygous plants were always classified with the resistant group. The reaction of heterozygotes to race *P* was not determined.

IV. DISCUSSION

Of the four new varieties investigated, three were shown to possess the Ml_u gene originally detected in Ulka. The varieties are P.I.92378 from Russia, P.I.181374 from Afghanistan, and Javelin-325. The latter variety derives its resistance from the amphiploid Iumillo × *Aegilops squarrosa*.

The fourth variety, Asosan, from Japan, was shown to possess a different gene which has been designated Ml_a.

The Australian work has revealed the presence of six genes conditioning the resistance of *T. vulgare* to *E. graminis tritici*. As compared with this, at least 12 genes are known to confer resistance of *Hordeum vulgare* to *E. graminis hordei* (Schaller and Briggs 1954).

Four of the six genes have been incorporated in a Federation background and will be used as tester lines in future physiological race determinations.

The pattern of behaviour of all varieties to the three races of *E. graminis tritici* has been consistent over the years and in conformity with the genetic constitution proposed for each variety. The genes responsible for the resistance of seven varieties to each of the three races are listed in Table 4.

Powers, Schafer, and Caldwell (1959) have recently reported a race of *E. graminis tritici* which is pathogenic to Asosan. They refer to unpublished data of Dr. T. M. Starling which indicates that Asosan possesses a single dominant gene conditioning mildew resistance which is distinct from those described by Carter (1954).

V. References

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