# DIFFERENTIAL REACTIONS TO THREE STRAINS OF WHEAT POWDERY MILDEW (*ERYSIPHE GRAMINIS* VAR. *TRITICI*)

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*Summary*

The pathogenicity of three strains of wheat powdery mildew on certain *Triticum* species and cultivars is described. One of these strains is characterized by virulence on the cultivar Asosan, previously resistant in Australian studies. Resistance, apparently genetically different from any already described, is recorded in two Australian cultivars. In view of the variability in pathogenicity revealed by these strains, the need for the establishment of an acceptable international differential set is emphasized.

## I. Introduction

Powdery mildew of wheat (*Erysiphe graminis* DC. var. *tritici* Marchal) does not cause serious economic losses in the major wheat growing areas of Australia and its importance is restricted to countries with cooler, more humid climatic conditions. However, the recent trend towards cultivation of dwarf wheats, mainly in the North American continent, has resulted in mildew becoming a more serious problem because their growth habit encourages mildew epiphytotics. If these types of wheat with potential high yielding ability become important in Australian breeding programs, a similar increase in importance of mildew could occur.

Mildew contamination has always presented a problem in wheat rust investigations, since mildew with its shorter incubation period sporulates before rust reaction types can be assessed. It is known that simultaneous infection with mildew can influence rust host–parasite interaction, resulting in a rust pustule of a more susceptible reaction type.

Studies in this Department are being conducted on the genetical basis of resistance to mildew in certain cultivars, especially those used for culturing rusts under glasshouse conditions, and on the location of the genes identified by monosomic analysis. To increase the range of suitable resistant genotypes, attempts are being made to incorporate mildew resistance from tetraploid and diploid *Triticum* species and allied genera into agronomic hexaploid wheats. In 42 chromosome types genetic and cytogenetic analyses can be conducted more appropriately because most interest is centred on bread wheat genetics. During the course of these investigations pathogenic variability was shown by the organism under glasshouse conditions on recognized differential cultivars and certain isolates were maintained for detailed studies. Routine testing of cultivars listed in the Sydney University Accession Register also revealed resistance(s) previously unrecorded in this connection.

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In this paper it is proposed to record the range in variability of three strains as indicated by their behaviour on certain cultivars, many of which carry identified genes for resistance, and to compare our results with varietal reactions from physiologic specialization surveys conducted by other workers. Waterhouse (1930) was the first to describe pathogenic variability in wheat powdery mildew, two strains being identified by their behaviour on the cultivar Thew. Two "physiologic forms" (equivalent to "strains", which term will be used henceforth), one of which was virulent on both Norka and Axminster, were also identified in the United States of America by Mains (1933). Since then numerous instances of strain variation have been recorded. These include reports by Vallega and Cenoz (1941) in Argentina; Taylor, Rodenhiser, and Bayles (1949), Lowther (1950), Powers, Schafer, and Caldwell (1959), and Scharen, Briggle, and Edwards (1964) in the United States of America; Pugsley and Carter (1953) and Pugsley (1961) in Australia; Nover (1957) in Europe; and Wolfe (1965) in the United Kingdom. The virulence on Asosan of certain strains (Powers, Schafer, and Caldwell 1959; Scharen, Briggle, and Edwards 1964) is of particular relevance to our studies.

## II. Methods and Materials

Three mildew strains, designated S.U.1, S.U.2, and S.U.3, were used in tests on selected hexaploid wheat cultivars and tetraploid and diploid *Triticum* species. Strain S.U.1 was isolated from conidia on the cultivar Federation W107* in a glasshouse at Sydney University where it has remained the prevalent strain, and is apparently identical with the predominant strain at Castle Hill Agricultural Research Station. It differs from the strain(s) used in initial tests at Sydney University by its ability to attack the cultivars Thew W203 and Federation$^4$ × Ulka W2515. S.U.2 was obtained as conidia from Waite Agricultural Research Institute, South Australia, in 1962 as Thew in glasshouses at that centre was resistant. The third strain, S.U.3, was isolated in 1965 from pustules on the previously immune cultivar Asosan × Federation$^5$ W2583, which has been used in this Department for culturing rusts. The strains were maintained as bulk conidial cultures, usually on the susceptible cultivar Federation, in widely separated glasshouses. Occasional contamination in a particular strain necessitated culturing on selected cultivars which were resistant to the other strains.

Cultivars of *T. aestivum* L. emend. Thell subsp. *vulgare* which were included in tests against the three strains, included, for the most part, those found resistant in strain surveys by previous investigators. Backcross derivatives Federation$^4$ × Ulka and Asosan × Federation$^5$ were used in place of Ulka and Asosan respectively; these lines were produced and described by Pugsley (1961). Cultivar S2303 W2044, which has been used in New Zealand in breeding for resistance, was included, as were two previously unrecorded resistant selections, Cowra No. 24 W150 and Plowman No. 3 W176, these having displayed resistance during routine testing of Sydney University wheat accessions. Concurrently lines of *T. aestivum* with resistance incorporated from certain other *Triticum* species or rye (*Secale cereale* L.) were tested. Federation and Huron R.L.20 W3028 were used as the standard susceptible cultivars;

* W numbers refer to the Sydney University Wheat Accession Register.

Redman W1942 and Chinese Spring W1806 were included in anticipation of their use in cytogenetical studies in the host, monosomic series being available in these cultivars.

Certain diploid and tetraploid *Triticum* species were also included in view of their immunity or high resistance in preliminary tests with strain S.U.1. Sets of differential cultivars have been inoculated with the three strains repeatedly and observations made over a complete year. Glasshouses used for the maintenance of two strains (S.U.1 and S.U.2) were not environmentally controlled and the effect of varying environmental conditions associated with seasonal changes on reaction type therefore could be assessed. Certain cultivars were included in isolated tests on the basis of pathogenic range revealed by the strains. Their reactions are described at pertinent stages in Section IV.

Seedlings were inoculated when the primary leaves were 2–4 in. in length by dusting with conidia from heavily infected Federation seedlings. Ten to 14 days after inoculation, depending on temperature, the mildew reaction types were scored according to the scheme devised by Newton and Cherewick (1947).

## III. Results

Seedling reaction types of selected cultivars of *T. aestivum* and of certain other species are presented in Table 1. Strain S.U.1 was virulent on Thew, Federation$^4$ × Ulka, Redman, and S2303, which were resistant to one or both of the other strains. Strain S.U.2 was unable to attack these cultivars, but selections W150 and W176, on the other hand, were moderately susceptible. Thew and Redman, in addition to Asosan × Federation$^5$, were susceptible to strain S.U.3. Of the diploid and tetraploid species tested, only Vernal Emmer W11 (*T. dicoccum* Schübl.) was susceptible, being attacked by S.U.3. Chinese Spring was moderately susceptible to each strain.

## IV. Discussion

Mildew strain S.U.2 had a restricted host range and apart from virulence on the susceptible control cultivars was able to attack only Cowra No. 24 and Plowman No. 3. Strain S.U.1 had a particularly wide susceptible host range; among the cultivars attacked were Thew, Federation$^4$ × Ulka, Chul W3030, and Redman; S2303 was moderately susceptible to this strain. Strain S.U.3, in addition to attacking Asosan × Federation$^5$, was characterized by virulence on Thew, Redman, and Vernal. Strains virulent on Asosan apparently have been recorded only by Powers, Schafer, and Caldwell (1959) and Scharen, Briggle, and Edwards (1964) in the United States of America.

The two Australian cultivars Cowra No. 24 and Plowman No. 3 reacted almost identically to the three strains. Their resistances are unexpected on the bases of their alleged origins. Cowra No. 24 is synonomous with Gullen (Macindoe and Walkden Brown 1958), whilst Plowman No. 3 is a farmers' selection from Bunyip released in 1915 (Fitzsimmons, personal communication). Since the selections were moderately susceptible to strain S.U.1 and immune or highly resistant to the other strains, they have been extremely useful in purifying strain S.U.2. Selections W150 and W176 behaved differentially to a recently detected strain in our glasshouses, W176 being

susceptible to it. To the three strains Asosan W3048 behaved identically to its backcross derivative W2583, which implies that Asosan probably has only a single gene for resistance. Vernal and Asosan reacted identically to the three strains in our tests; however, Scharen, Briggle, and Edwards found no parallel behaviour in the two cultivars, suggesting that their genetic bases for resistance are different.

TABLE 1

MEAN SEEDLING REACTIONS AND REACTION TYPES OF ACCESSIONS OF VARIOUS *TRITICUM* SPECIES TO THREE STRAINS OF WHEAT POWDERY MILDEW

R, resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible. Numerals and other symbols adjacent to these letters are scores based on a scheme devised by Newton and Cherewick (1947)

| Species and Cultivar | Wheat Accession Register No. | Reaction and Reaction Type | | | | | |
|---|---|---|---|---|---|---|---|
| | | Strain S.U. 1 | | Strain S.U. 2 | | Strain S.U. 3 | |
| *Triticum aestivum* L. emend. Thell subsp. *vulgare* | | | | | | | |
| Federation | W107 | S | 4 | S | 4 | S | 4 |
| Huron R.L. 20 | W3028 | S | 4 | S | 4 | S | 4 |
| Chinese Spring | W1806 | MS | 3 | MS | 3 | MS | 3 |
| Thew | W203 | S | 4 | R | 0 | S | 4 |
| Federation[4] × Ulka | W2515 | S | 3+*n* | R | ;*nn*, 1−*nn* | R | ;*nn* |
| Cowra No. 24 | W150 | R | 01− | MS | 3− | R | 0 |
| Plowman No. 3 | W176 | R | 01− | MS | 3 | R | 01− |
| Chul | W3030 | S | 4 | R | ; | R | ; |
| Redman | W1942 | S | 4 | R | ;1− | S | 4 |
| Asosan × Federation[5] | W2583 | R | 0 | R | 0 | S | 4 |
| S2303 | W2044 | MS | 3− | R | ; | R | ; |
| *T. timopheevi* Zhuk. derivative | W1656 | MS | 3− | R | ; | R | ; |
| H13471 (resistance from *T. durum* Desf.) | W3025 | S | 3+ | R | 0 | R | 0 |
| H14/44 (resistance from *Secale cereale* L.) ($2n=44$) | W3021 | R | 1− | R | 1− | R | 1− |
| Weihenstephaner M. 1 (resistance from *T. persicum* Vav.) | W3026 | R | 0 | R | 0 | R | 0 |
| *T. durum* Desf. cv. Yuma | W3052 | R | 0 | R | 0 | R | 0 |
| *T. dicoccum* Schübl. | | | | | | | |
| Vernal Emmer | W11 | R | 0; | R | 0; | S | 4 |
| Khapli Emmer | W12 | R | 0 | R | 0 | R | 0 |
| Unnamed | W2698 | R | 0 | R | 0 | R | 0 |
| *T. timopheevi* Zhuk. (unnamed) | W1899 | R | 0 | R | 0 | R | 0 |
| *T. persicum* Vav. (unnamed) | W3047 | R | 0 | R | 0 | R | 0 |
| *T. monococcum* L. Einkorn | W10 | R | 0 | R | 1− | R | 0 |

Genes for resistance documented in cultivars tested in Table 1 are, on the terminology proposed by Pugsley and Carter (1953) and Pugsley (1961), as follows:

Thew ($Ml_t$), Federation[4] × Ulka ($Ml_u$), Chul ($Ml_c$),

Asosan × Federation[5] ($Ml_a$).

Carter (1954) showed that the cultivar Normandie W3029 possesses the genes $Ml_t$ and $Ml_u$. On the basis of its genotype, Normandie behaved as expected when tested to the three strains, being susceptible to strain S.U.1. Line W3049 produced at Sydney University by combining the genes $Ml_t$ from Fedka W2412 (Federation$^4$ × Kenya W744) and $Ml_u$ from Federation$^4$ × Ulka W2515, in a Federation background behaved identically to Normandie. To strain S.U.2 the Thew "0" reaction type was epistatic to the ";*nn*" (pronounced necrosis) reaction type characteristic of Ulka; gene $Ml_t$ was ineffective to strain S.U.3 and a ";*nn*" reaction type due to the $Ml_u$ gene manifested. A comparison of the reactions of Normandie and W3049 in strain surveys may well reveal additional genes for resistance in Normandie.

H14/44 W3021, deriving its resistance from rye and Weihenstephaner M.1 W3026, with resistance from *T. persicum* Vav., were immune or highly resistant to all strains; W3021 has a pair of rye chromosomes added to hexaploid wheat (Wolfe 1965). *T. persicum* W3047, the source of resistance in Weihenstephaner M.1, was, as expected from the reaction of the latter cultivar, immune to all strains. H13471 W3025, with resistance derived from *T. durum* Desf., proved susceptible to strain S.U.1. However, cv. Yuma W3052, belonging to this species, was immune to all strains.

*T. timopheevi* Zhuk. derivative W1656 C.I.16232, resistant to two strains, was moderately susceptible to strain S.U.1 exhibiting a "3—" reaction type. *T. timopheevi* W1899 maintained immunity to all strains indicating that further gene(s) for resistance, additional to that transferred to W1656, are present in this species. Nyquist (1963) reported that mildew resistance in C.I.12633 was conditioned by at least two genes, at least one of which was linked with a gene for stem rust resistance.

Two accessions of *T. dicoccum*, Khapli Emmer W12 and W2698, were immune to mildew. Einkorn W10 (*T. monococcum* L.) showed slight symptoms of infection with strain S.U.2. Immunity or resistance in these 28- and 14-chromosome species can almost certainly be transferred to increase genetic diversity for host resistance at the hexaploid level.

The cultivar Sonora has been included in most mildew strain surveys. The resistance of Sonora has been shown to be due to the dominant gene $Ml_s$ (Pugsley and Carter 1953). Wolfe (1965) considered that Sonora and Sturgeon (also possessing $Ml_s$), gave inconsistent results when compared with each other and when tested in different environments. In the present studies, Sonora W195 was similarly unsatisfactory, although less variation was shown on secondary and later leaves.

Strain S.U.1 has arisen, presumably by mutation for increased range in host susceptibility, from a strain resembling S.U.2, since in Sydney University glasshouses Fedka, and then W3049, used for culturing rusts, have become susceptible in turn to new mildew strains. The origin of strain S.U.3 is difficult to explain on the basis of mutation from one of the other two strains described since it differs from each in pathogenicity to several cultivars, and from both in its ability to attack Vernal. The suggestion that it is a recombinant between the other two strains is likewise difficult to comprehend unless recombination was also accompanied by at least one mutation, or that recombination involved segregation of suppressor genes present in both of the parent strains.

Comparisons of the pathogenicity of strains we have described with any designated elsewhere are invalidated because the range of differentials is not strictly comparable in any instance. Strain S.U.2 closely resembles P-1 designated by Pugsley (1961); of the 30 strains listed by Wolfe (1965) as occurring in the United Kingdom and Europe, it is similar to strain O on differentials common in both tests. A system of strain designations which will be adopted by workers in different centres is required. The best principle in describing strains of a plant-pathogenic fungus is that applied to potato late blight [*Phytophthora infestans* (Mont.) de Bary], where the basis is virulence on specific *Solanum demissum* Lind. genes for resistance (Black *et al.* 1953).

The adoption of this scheme in wheat mildew would involve the isolation of documented genes for resistance, preferably in a uniform genetic background, such as Pugsley (1961) has done in certain instances. Meanwhile sufficient host genetic variability has been shown from our studies to establish a differential set comprising different genotypes used previously by other investigators, but enlarged to include certain additional accessions. The reactions of "supplemental" cultivars or species added subsequently can be used in making strain designations more explicit. This is the basis of a scheme proposed by Watson and Luig (1961) for the classification of strains of wheat leaf rust, *Puccinia recondita* Rob. ex Desm., where certain cultivars outside the international differential set have proven essential in describing strain variability.

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