

## A Study of Physiologic Specialization of Rye Stem Rust in Australia

B. H. Tan,<sup>A</sup> I. A. Watson and N. H. Luig

Plant Breeding Institute, University of Sydney, Sydney, N.S.W. 2006.

<sup>A</sup> Present address: Max Planck Institut für Züchtungsforschung, Köln-Vogelsang, 5 Köln 30, West Germany.

### Abstract

Self-fertile lines of *Secale cereale* possessing single genes for resistance were successfully used to differentiate between Australian cultures of *Puccinia graminis secalis* and of putative *P. graminis tritici* × *secalis* hybrids. The technique, which is economical of seed and yields repeatable results, represents a significant improvement over older procedures.

### Introduction

The existence in Australia of rye stem rust, *Puccinia graminis* Pers. f. sp. *secalis* Eriks. & E. Henn., has been recognized only relatively recently (Waterhouse 1957). Prior to 1957 stem rust commonly had been observed on individual plants of rye but in all cases investigated this was found to be *P. graminis* f. sp. *tritici* Eriks. & E. Henn. (Waterhouse 1957). Little is known of the variability of *P. graminis secalis* in this country except that Watson and Luig (1958) noted that there were three groups of isolates in Tasmania which could be distinguished by their differential behaviour on the bread wheat (*Triticum aestivum* L.) Little Club. Barberry bushes, *Berberis vulgaris* L., on which the sexual stage of *P. graminis secalis* occurs, are widespread in Tasmania. On the mainland *B. vulgaris* is rare, and infection is uncommon. However, when it does occur the rust involved is *P. graminis secalis* or a *forma specialis* specific for some naturalized grass.

*P. graminis secalis* can hybridize somatically with wheat stem rust under laboratory conditions (Bridgmon and Wilcoxson 1959; Watson and Luig 1959). Luig and Watson (1972) suggested that under natural conditions such hybridization also takes place on congenial wild grasses, particularly rough wheat grass (*Agropyron scabrum* Beauv.), a native species occurring commonly in north-eastern Australia (see Rees 1972). It was, therefore, postulated *a priori* that there is genetic variability in the Australian rye stem rust flora, and the aim was to test the validity of this proposition.

Levine and Stakman (1923) claimed that in North America, *P. graminis secalis* comprised at least two, and probably three, physiologic forms identified by their differential behaviour on three open-pollinated rye cultivars. When three more differentials were added and rust isolates from Europe were also tested, fourteen physiologic forms could be distinguished (Cotter and Levine 1932). Hitherto Australian biotypes of rye stem rust have been recognized by different infection types produced on the bread wheats Little Club and W2691 (a line selected for susceptibility to *P. graminis secalis*). In the study reported herein the technique has been refined so that lines of *Secale cereale* that are each homozygous for a single gene for

resistance to stem rust are used (Tan 1973). By this approach several cultures of putative hybrids between wheat and rye stem rusts were also differentiated.

## Materials and Methods

### Differential Hosts

A set of host plants consisting of the open-pollinated rye cultivar Black Winter and of the wheats Little Club, W2691 and Sonora W195 was found useful for the preliminary discrimination between *P. graminis secalis*, *P. graminis tritici* and *secalis*  $\times$  *tritici* hybrid cultures. Black Winter rye, which is susceptible to rye stem rust, shows a mixture of resistant and susceptible seedlings to the hybrids but is resistant to wheat stem rust. Little Club and W2691 give intermediate reaction types with most hybrid cultures, whereas Sonora is susceptible only to strains of *P. graminis tritici*.

The main set of differential hosts used comprised progenies of eight  $F_3$  lines from crosses between resistant and susceptible inbred lines of *S. cereale*. Although only four resistant parents were used, each line has been shown to be homozygous for a different major gene conferring resistance to one or more cultures of *P. graminis tritici*, *P. graminis secalis*, and/or hybrids between them (Tan 1973). The genes involved have been designated provisionally *SrA*, *SrB*, *SrC*, *SrD*, *SrG*, *SrH*, *SrI* and *SrJ*. Except for *SrB* and *SrI*, which are either allelic or tightly linked, these genes segregate independently in genetic studies.

Table 1. Source of eight field collections of *P. graminis*

Type	Culture No.	Original host	Location
<i>P. graminis secalis</i>	71327	<i>Agropyron scabrum</i>	Holbrook, N.S.W.
	71523	<i>Hordeum vulgare</i>	Wagga Wagga, N.S.W.
	72594	<i>Secale cereale</i>	Cootamundra, N.S.W.
	69208-3	<i>Berberis vulgaris</i>	Meadow Flat, N.S.W.
	71008	<i>A. scabrum</i>	Jondaryan, Qld
<i>P. graminis tritici</i> $\times$ <i>P. graminis secalis</i>	71406	<i>H. vulgare</i>	Cecil Plains, Qld
	70112	<i>A. scabrum</i>	Melrose, Qld
	73080	<i>A. scabrum</i>	Purrawunda, Qld

### Cultures of *P. graminis*

The eight cultures used in this study were collected from a variety of hosts over an extensive area of the eastern part of Australia (Table 1).

The stem rust inocula used in the tests originated as single pustules on Black Winter rye or, in the case of the putative hybrid strains, on W2691.

Rust inoculations were made by using a pressure atomizer to disperse uredospores suspended in a small quantity of a light, non-phytotoxic paraffinic oil (Rowell 1957) over seedlings at the first leaf stage. After incubation for 16-20 h in a room maintained at high humidity, the pots containing the seedlings were placed on glasshouse benches and kept at temperatures of 15-22°C. Infection types on the first leaf were classified approximately 14 days after inoculation according to the key prepared by Stakman *et al.* (1962).

## Results and Discussion

The efficacy of host genes *SrC*, *SrD*, *SrG* and *SrH* for differentiating the eight cultures of *P. graminis secalis* and putative hybrids is demonstrated by the infection types recorded in Table 2. Lines with genes *SrI* and *SrJ*, which in previous studies (Tan 1973) were found to be effective only against strains of wheat stem rust, were resistant to the three putative hybrid cultures 71406, 70112 and 73080 but semi-susceptible or susceptible to the five cultures belonging to *P. graminis secalis*. Similar

relationships apply to the line with *SrB* except that, of the cultures 70112, 73080 and 71406, only the last one was avirulent on this line. The supposed hybrid origin of these three cultures is thus supported by their avirulence on the lines with *SrI* and *SrJ* (and in the case of 71406 also on the line with *SrB*) and by their behaviour on lines with genes *SrC*, *SrD*, *SrG* and *SrH*.

*SrA* which can distinguish the old standard race 126 of *P. graminis tritici* from the present Australian strains of stem rust (Tan 1973) did not react differentially to the eight cultures. The above results support the suggestion that *P. graminis tritici* and *P. graminis secalis* differ only in a limited number of genes for avirulence which correspond to the host genes in rye and wheat respectively (Watson and Luig 1968).

Table 2. Infection types<sup>A</sup> produced at 15–22°C by eight field cultures of *P. graminis secalis* and putative hybrids on eight rye lines possessing single genes for resistance (*Sr*)

Rust culture No. <sup>B</sup>	Host line with <i>Sr</i> gene							
	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>G</i>	<i>H</i>	<i>I</i>	<i>J</i>
71327(S)	;	3+	;2≡	22+	12≡	3	3	3
71523(S)	;	3+4	;2≡	2	2+	22+	3	2+3–
72594(S)	;	3+	2=	3+	1	3+	3+	3+4
69208–3(S)	;	3+	3+	3+	;1	3+	3+	3+
71008(S)	;	3+4	;2=	2+	3–	33+	3	3
71406(H)	; <sup>N</sup>	2=	3	3	2≡2=	;	;3≡ <sup>N</sup>	12≡
70112(H)	; <sup>N</sup>	3+	2=	2+3=	3	2	; <sup>NN</sup>	2≡
73080(H)	;	3	;12≡	3	3–	2+3–	; <sup>NN</sup>	12≡

<sup>A</sup> After Stakman *et al.* (1962).

<sup>B</sup> S = *P. graminis secalis*, H = *P. graminis tritici* × *P. graminis secalis*.

<sup>N</sup> Necrosis.

Two decades ago rye was unimportant as a crop in Australia by comparison with wheat, oats and barley, but it was resistant to stem rust. Due to recent changes in demand for rye bread, and the increase in area sown to rye, *P. graminis secalis* has become more common. Rye crops heavily infected by *P. graminis secalis* have been commonly observed over the last five years. The present study, from a small number of collections, shows that at least five strains of *P. graminis secalis* occur in eastern Australia. Undoubtedly, more strains are present, especially in Tasmania where hybridization occurs on the alternate host (Watson and Luig 1958).

The eight *Sr* genes listed in Table 2 were derived from only four parental lines of *S. cereale*. It is reasonable to assume that further *Sr* genes can be isolated, and, if so, this would allow a more complete separation of the strains of *P. graminis secalis*.

The origin of the five strains of rye stem rust isolated in this study remains speculative. The original *P. graminis secalis* in Australia could have been introduced aerially from other continents, or alternatively it could have evolved through hybridization between other *formae speciales* existing at that time. Once established on *S. cereale*, sexual hybridization in Tasmania (Watson and Luig 1958) or somatic hybridization on congenial wild and cultivated hosts (Watson and Luig 1959; Luig and Watson 1972) could lead to further variability in virulence. Whatever the mode of origin, it is apparent that there exists a wide diversity of strains in Australia without any selection resulting from the growing of resistant cultivars of rye.

The notable difference of this work from that previously reported (Levine and Stakman 1923; Cotter and Levine 1932) is that earlier workers used three, or six, heterogeneous commercial varieties as differentials. Consequently, varietal reactions had to be assessed on the basis of the proportion of resistant and susceptible seedlings in any one test. Because of this genetic heterogeneity there is doubt that some of their experimental results can be repeated. This inherent weakness of the early work has now been overcome by employing lines which are homozygous with respect to an Sr gene. Moreover, these lines with single genes for resistance have the greatest power in resolving variability (Flor 1954). This material has been derived from self-fertile parents and seed from it can be increased by bagging ears of plants during anthesis, or by growing individual lines in isolation. Another feature of the procedure is the comparatively small number of seedlings required for each test. For example, Cotter and Levine (1932) reported having to inoculate up to 200 seedlings in some tests to achieve a reliable score.

Our experiments have been repeated at different times of the year, as well as utilizing lines different from those used here but which possessed the same eight genes for resistance. The results were essentially the same when allowance was made for small differences in environmental conditions.

The lines with the Sr genes developed for the present study are available for distribution.

### Acknowledgments

We are grateful for the help of J. D. Oates and A. W. Jackson. The work was conducted while the senior author held a Sydney University Postgraduate Studentship. Financial assistance was also provided by the Wheat Industry Research Council of Australia.

### References

- Bridgmon, G. H., and Wilcoxson, R. D. (1959). New races from mixtures of uredospores of varieties of *Puccinia graminis*. *Phytopathology* **49**, 428-9.
- Cotter, R. U., and Levine, M. N. (1932). Physiologic specialization in *Puccinia graminis secalis*. *J. Agric. Res.* **45**, 297-315.
- Levine, M. N., and Stakman, E. C. (1923). Biologic specialization of *Puccinia graminis secalis*. *Phytopathology* **13**, 35.
- Luig, N. H., and Watson, I. A. (1972). The role of wild and cultivated grasses in the hybridization of *formae speciales* of *Puccinia graminis*. *Aust. J. Biol. Sci.* **25**, 335-42.
- Flor, H. H. (1954). Identification of races of flax rust by lines with single rust-conditioning genes. U.S. Dept. Agric. Tech. Bull. 1087.
- Rees, R. C. (1972). *Agropyron scabrum* and its role in the epidemiology of *Puccinia graminis* in north-eastern Australia. *Aust. J. Agric. Res.* **23**, 789-98.
- Rowell, J. B. (1957). Oil inoculation of wheat with spores of *Puccinia graminis* var. *tritici*. *Phytopathology* **47**, 689-90.
- Stakman, E. C., Stewart, D. M., and Loegering, W. Q. (1962). Identification of physiologic races of *Puccinia graminis* var. *tritici*. Agric. Res. Sta., U.S. Dept of Agriculture, E617. (Revised.)
- Tan, B. H. (1973). The genetics of resistance to *Puccinia graminis* Pers. in the genus *Secale*. Ph.D. Thesis, University of Sydney.
- Waterhouse, W. L. (1957). Australian rust studies. XV. The occurrence in Australia of stem rust of rye, *Puccinia graminis secalis* E. & H. *Proc. Linn. Soc. N.S.W.* **82**, 145-6.
- Watson, I. A., and Luig, N. H. (1958). Widespread natural infection of barberry by *Puccinia graminis* in Tasmania. *Proc. Linn. Soc. N.S.W.* **83**, 181-6.

- Watson, I. A., and Luig, N. H. (1959). Somatic hybridization between *Puccinia graminis* var. *tritici* and *Puccinia graminis* var. *secalis*. *Proc. Linn. Soc. N.S.W.* **84**, 207-8.
- Watson, I. A., and Luig, N. H. (1968). The ecology and genetics of host-pathogen relationships in wheat rusts in Australia. *Proc. 3rd Int. Wheat Genet. Symp.*, Canberra, Australia. pp. 227-38.

Manuscript received 28 January 1975

