Virulence in Puccinia coronata f. sp. avenae and P. graminis f. sp. avenae in New Zealand

J. W. Martens, P. A. Burnett, and G. M. Wright

Plant Pathologist, Agriculture Canada, Research Station, 195 Dafoe Road, Winnipeg, Canada R3T 2M9; and Plant Pathologist and Plant Breeder, respectively, Dept. of Scientific and Industrial Research, Crop Res. Div., Private Bag, Christchurch, N. Z.

Contribution No. 785, Agriculture Canada, Research Station, Winnipeg, Manitoba, Canada R3T 2M9.

We are grateful to I. Harvey and J. Hedley, Plant Diagnostic Laboratory, Ministry of Agriculture and Fisheries (MAF) Lincoln; C. I. Derrett, R. B. Gordon, P. Irvine, J. Logan, and R. C. Mainprize, MAF, for submitting rust samples from throughout the country; and to R. I. H. McKenzie and D. S. C. Wright for increasing the differential seed stocks.

Accepted for publication 24 May 1977.

ABSTRACT

MARTENS, J. W., P. A. BURNETT, and G. M. WRIGHT. 1977. Virulence in Puccinia coronata f. sp. avenae and P. graminis f. sp. avenae in New Zealand. Phytopathology 67:1519-1521.

Virulence in the *Puccinia coronata* population on oats in New Zealand was studied using as differentials: 12 single *Pc*-gene lines; the International Differential Set; and local cultivars and selections. Sixteen virulence combinations were determined from 93 isolates; most isolates carried apparently unnecessary and not-selected-for virulence on a number of genes for resistance that are not known to have occurred in New Zealand. The rust populations on the North and South Islands had different frequencies of genes for virulence. In contrast, the single *Pg*-gene lines differentiated only three virulence combinations in *Puccinia graminis* and no virulence was observed on lines with *Pg* 1, 2, 4, 8, or 13 even though genes *Pg* 2 and 4 have occurred in the host population for a long time. *Puccinia graminis* from oats was also virulent on some cultivars of barley.

Additional key words: epidemiology, *Avena sativa*, *Hordeum vulgare*, *Hordeum distichon*.

Oat (*Avena sativa* L.) crown rust and stem rust, which are caused respectively by *Puccinia coronata* Cda. f. sp. *avenae* Eriks. and *P. graminis* Pers. f. sp. *avenae* Eriks. and E. Henn., were first distinguished in New Zealand by Cunningham (2). The rusts occur on both Islands wherever oats are grown, and can overseason in the uredial stage on oats and possibly on other grasses. Since 1935 (7), when rust cultures were first sent overseas for study, there has been continuing cooperation with rust workers at the University of Sydney, Australia (4). Cruickshank (1), using the International Set of Differentials, completed the first study of physiologic specialization of *P. coronata avenae* in New Zealand.

The present study was undertaken to determine the virulence of New Zealand rusts on recently discovered sources of resistance to which the rusts have not yet been exposed, to study the resistance-virulence relationship in a relatively isolated island epidemiological unit, and to relate this to cultivar improvement breeding programs in New Zealand.

MATERIALS AND METHODS

Uredial rust spore collections were obtained from growers' fields throughout the oat-growing areas of New Zealand and from various genotypes in the hybrid oat nurseries at Gore and Lincoln (South Island) and at Palmerston North (North Island). The spores were scraped from infected leaves and stems with a sterile scalpel and transferred for increase to the cultivar Victory, a universally susceptible host. The test cultivars or lines were inoculated by rubbing the first leaves with moistened, spore-laden cotton swabs. The inoculated seedling plants were incubated for 24 hr under high humidity and then placed in a shaded glasshouse with natural light. Differential and supplementary sets for *P. coronata avenae* included the local, commonly-grown cultivars and promising selections, the International Differentials used in the 1952-1955 study (1), and 12 single *Pc*-gene lines (8) derived from *A. sterilis*, backcrossed to the cultivar Pendek (Tables 1, 2). The *P. graminis avenae* differential and supplementary sets included the local cultivars and seven, *Pg*, single-resistance-gene lines (8) in the Rodney O background (Table 3). The virulence combination descriptions follow the system in use for cereal rusts in Canada (3, 6). Hosts with infection types of 0 to 2+ (9) are considered resistant and appear in the numerator of the virulence formulae; those with infection types 3 to 4 are considered susceptible and appear in the denominator (Tables 1, 3). Six different *P. graminis avenae* cultures also were tested for pathogenicity on a group of barley cultivars (*Hordeum vulgare* L. and *H. distichon* L.).

RESULTS AND DISCUSSION

The *P. coronata avenae* population of New Zealand contained many virulence combinations (Table 1), including a wide range of virulence on sources of resistance

that are not known to have occurred in the host population of the country. Moreover, isolates from the North Island are distinctly different than those from the South Island (Table 2) in terms of virulence on lines with the *Pc*-genes and also on the differentials in the International Set (Table 2-A). Virulence was common on lines with *Pc*-genes 35, 38, 40, 47, and 54, yet none of these sources of resistance has been used commercially in New Zealand (Table 2-C). However, lines with *Pc* 39, 45, 48, 50, 55, and 56 were highly effective against the prevailing rust. It should be noted that in 2 yr of field trials at Lincoln, lines with *Pc* 35, 38, and 39 all were observed to be immune in the adult stage (G. M. Wright, *personal communication*). Similarly, good resistance was observed in "single-gene" lines with these genes in the hybrid nursery at Gore in 1974, but lines with gene *Pc* 40 were highly susceptible at the same location (R. I. H. McKenzie, *personal communication*).

Puccinia coronata isolates obtained from both islands commonly were virulent on the International Differentials Appler, Bondvic, Landhafer, and Trispernia; isolates from the North Island only also showed a high frequency of virulence on the differentials Santa Fe, Ukraine, and Victoria. Less than 20% of the isolates were virulent on

TABLE 1. Virulence combinations of *Puccinia coronata avenae* isolates on backcross lines of oats with single genes for crown rust resistance in New Zealand in 1975-1976.

Avirulence/virulence formulae (*Pc*-genes)[a]	No. of isolates: North Island	South Island	Total	Percent of total isolates
35, 38, 39, 45, 47, 48, 50, 54, 55, 56/40, 46		8	8	8.6
35, 38, 39, 45, 47, 48, 50, 55, 56/40, 46, 54	3	3	6	6.5
35, 38, 39, 45, 48, 50, 55, 56/40, 46, 47, 54		2	2	2.2
38, 39, 45, 47, 48, 50, 54, 55, 56/35, 40, 46	1	8	9	9.6
38, 39, 45, 47, 48, 50, 55, 56/35, 40, 46, 54	5	5	10	10.8
38, 39, 45, 48, 50, 54, 55, 56/35, 40, 46, 47	2	3	5	5.4
38, 39, 45, 48, 50, 55, 56/35, 40, 46, 47, 54	5	3	8	8.6
39, 40, 45, 47, 48, 50, 54, 55, 56/35, 38, 46	1		1	1.1
39, 40, 45, 48, 50, 54, 55, 56/35, 38, 46, 47	1		1	1.1
39, 45, 46, 47, 48, 50, 55, 56/35, 38, 40, 54	1		1	1.1
39, 45, 47, 48, 50, 54, 55, 56/35, 38, 40, 46	1	6	7	7.5
39, 45, 47, 48, 50, 55, 56/35, 38, 40, 46, 54	2	2	4	4.3
39, 45, 47, 48, 50, 56/35, 38, 40, 46, 54, 55		1	1	1.1
39, 45, 48, 50, 54, 55, 56/35, 38, 40, 46, 47	3		3	3.2
39, 45, 48, 50, 55, 56/35, 38, 40, 46, 47, 54	13	13	26	28.0
39, 48, 50, 54, 55, 56/35, 38, 40, 45, 46, 47		1	1	1.1
	38	55	93	

[a]The *Pc*-gene numbers are designations assigned to defined single gene sources of resistance according to a standardized international system of nomenclature [Simons et al. 1977. U.S. Dep. Agric. Handb. (In press)].

TABLE 2. Virulence of isolates of *Puccinia coronata avenae* on various oat genotypes in New Zealand in 1975-1976

Differentials and no. of isolates per source		Pathogen virulence (% isolates virulent) on specific cultivars or lines										
A. International diff. set:		Anthony	Appler	Bond	Bondvic	Landhafer	Saia	Santa Fe	Trispernia	Ukraine	Victoria	
North Island	(38)	20	88	5	63	45	5	40	50	48	38	
South Island	(55)	13	85	5	62	33	7	13	49	5	0	
1952-1953[a]	(53)	66	100	42	2	0	34	2	2	2	2	
1954-1955[a]	(80)	30	100	2	29	12	4	12	29	6	0	
B. Commercial cultivars:		Amuri	Avon	Makuru	Okawa	Omihi/2	Orti/4	Oware	Taiko	433	Hudson	
North Island	(38)	73	100	100	100	95	100	100	100	43		
South Island	(55)	80	100	100	100	93	100	100	100	2		
C. Single-gene backcross lines:		*Pc*35	*Pc*38	*Pc*39	*Pc*40	*Pc*45	*Pc*46	*Pc*47	*Pc*48	*Pc*50	*Pc*54	*Pc*55	*Pc*56
North Island	(39)	92	58	0	95	0	97	63	0	0	29	0	0
South Island	(55)	76	42	0	100	2	100	40	0	0	55	2	0

[a]These virulence data were derived from a study published by Cruickshank (1).

TABLE 3. Virulence combinations of *Puccinia graminis avenae* isolates on backcross lines of oats with single genes for stem rust resistance in New Zealand in 1975-1976

Avirulence/virulence formulae (*Pg*-genes)[a]	No. of isolates	Percent of total isolates
1, 2, 3, 4, 8, 9, 13/	1	2
1, 2, 3, 4, 8, 13/9	21	35
1, 2, 4, 8, 13/3, 9	38	63

[a] The *Pg*-gene numbers are designations assigned to defined single gene sources of resistance according to a standardized international system of nomenclature. [Simons et al. 1977. U.S. Dept. of Agric. Handb. (In press).]

Anthony, Bond, and Saia. A comparison of these results with those obtained 20 yr ago indicates a decrease in virulence on Bond and Saia and increases in virulence on Bondvic, Landhafer, Santa Fe, Trispernia, Ukraine, and Victoria. No isolate was virulent on the cultivar Ascencao, which was included in a supplemental set.

The commercially grown cultivars and selections (Table 2-B), with the exception of Amuri and Omihi/2, were susceptible in the seedling stage to all isolates tested. However, good resistance was normally expressed by Avon, Okawa, and Omihi/2, and moderate resistance was expressed by Amuri and Oware (infection type 1-2) in the naturally infected nursery at Lincoln.

Amuri (released in 1965) and Oware (released in 1963) were produced at Lincoln by backcrossing resistance from Victoria and the "original" Garry, respectively. Both had a good level of adult plant resistance when released. Okawa is a more recent selection from a cross involving "original" Garry and probably has more of the original resistance from Victoria than do Amuri or Oware. Omihi/2 is a selection from a cross involving the cultivar Avon.

In sharp contrast to the *P. coronata avenae* variability, only three virulence combinations, all relatively avirulent, were found in *P. graminis avenae* (Table 3). Only *Pg* 3 and *Pg* 9 were ineffective against most isolates tested. The resistance in Okawa and Omihi/2 is conferred by genes *Pg* 2 and *Pg* 4, from Garry and Rodney, respectively.

When a number of barley cultivars were inoculated in the seedling stage with six different cultures of *P. graminis avenae*, all six infected some of the cultivars. The barley cultivars Carlsberg, Hassan, Julia, Kea, Lenta, Manapou, and Sultan were immune: Betzes, Bonanza, Fergus, Galt, Kakapo, Kaniere, Research, and Ruby appeared to react differentially to the six cultures, but not enough interactions were studied to draw definite conclusions. Hector, Mata, Peguis, and Zephyr consistently produced infection type-2 and type-3 pustules that sporulated fairly well. The immunity observed with some cultivars did not appear to be conferred by the Peatland (C. I. 5267) gene for resistance to *P. graminis* because Carlsberg, Julia, and Lenta do not have it and were immune, whereas Peguis has it and was not immune. Two of these *P. graminis avenae* cultures were transferred from barley to both oats and barley and in turn subtransfers from these were made to both hosts successfully. However, more and larger pustules usually developed on oats.

The presence of so much "unnecessary and not-selected-for" virulence in the *P. coronata avenae* seems surprising. The role of other hosts, such as grasses, that give selective advantage to biotypes with a wide virulence range, pleiotropy, or simply chance occurrence may be part of the answer. Differences in virulence combinations between the Islands suggest that they are relatively independent epidemiological units. The Cook Strait inter-island distance is less than 100 km and is not likely a major barrier. The year-round availability of host plants, combined with a north to south crop maturity progression and few winds in the same direction, and dissimilar climatic conditions may account for the differences.

The *P. graminis avenae* genetic simplicity and lack of virulence, even though the resistance of Achilles, conditioned by genes *Pg* 2 and *Pg* 4, has been used in the country for three decades, is unlike the situation in Eastern Australia, the nearest large land mass. There, 22 virulence combinations have been described and only one gene, *Pg* 8, confers effective resistance (4). Although trans-Tasman inoculum transfer almost certainly occurs, this does not appear to be a major determinant of physiologic specialization in New Zealand, as it appears to be for the wheat stem rust (5).

In terms of breeding for rust resistance, there is an abundance of sources that could be used to develop a number of cultivars, each with a separate group of genes for resistance to both organisms.

LITERATURE CITED

1. CRUICKSHANK, I. A. M. 1956. Physiologic specialization of oat crown rust (Puccinia coronata f. sp. avenae) in New Zealand. N. Z. J. Sci. Technol 38:359-362.
2. CUNNINGHAM, G. H. 1922. Some recent changes in the names of plant diseases. N. Z. J. Agric. 24:96-102.
3. HARDER, D. E. 1975. Crown rust of oats in Canada in 1974. Can. Plant Dis. Surv. 55:63-65.
4. LUIG, N. H., and E. P. BAKER. 1973. Variability in oat stem rust in Eastern Australia. Proc. Linn. Soc. N. S. W. 98:53-61.
5. LUIG, N. H., and I. A. WATSON. 1970. The effect of complex genetic resistance in wheat on the variability of Puccinia graminis f. sp. tritici. Proc. Linn. Soc. N. S. W. 95:22-45.
6. MARTENS, J. W. 1975. Stem rust of oats in Canada in 1974. Can. Plant Dis. Surv. 55:61-62.
7. NEW ZEALAND. DEPT. OF SCIENTIFIC AND INDUSTRIAL RESEARCH. 1935. Page 19 *in* 1935 Annual Report.
8. SIMONS, M. D., J. W. MARTENS, R. I. H. Mc KENZIE, I. NISHIYAMA, K. SADANAGA, J. SEBESTA, and H. THOMAS. 1977. Genedex Avena International – a standardized system of nomenclature for genes and chromosomes of oats, and a catalog of genes governing characters of oats. Rev. I. U.S. Dep. Agric. Handb. U.S. Gov't. Printing Office, Washington, D.C.
9. STAKMAN, E. C., D. M. STEWART, and W. Q. LOEGERING. 1962. Identification of physiologic races of Puccinia graminis var. tritici. U.S. Dept. Agric., Agric. Res. S. Bull. E617 (Review).