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Temperature-sensitive adult plant leaf rust resistance in bread wheat (*Triticum aestivum* L.)

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Summary. Temperature sensitivity of the adult plant resistance shown by 16 bread wheat lines against race 77-5 of *Puccinia recondita* (the most common and virulent) on the Indian sub-continent was studied. The infection types on these 16 lines were also compared with those of the known adult plant resistance genes *Lr12, Lr13, Lr22a, Lr22b, Lr34* and *Lr37*. Frontana, CIM25 (a leaf-rust resistant breeding line), Pavon 76, Pari 73 and Flinders carried low-temperature adult plant resistance (LTAP) which was expressed only at 14.5°C. The adult plant resistance of Chris, Arz, Mukta, WW15(R) and VL421 was best expressed at 30°C, and these 5 wheats carried high temperature adult plant resistance (HTAP). The adult plant resistance of WH291 was expressed equally at 14.5, 20 and 30°C. The infection pattern of Mentana, WL410, IWP72, HD2204 and Son-Kl-Rend was similar to that of Thatcher near-isogenic lines carrying the genes *Lr22a* and *Lr37* and their adult plant resistance was expressed only at 20°C. The Thatcher near-isogenic lines carrying the genes *Lr12, Lr13, Lr22b* and *Lr34*, and WL711 having the gene *Lr13* did not show resistance against race 77-5.

Key words: *Puccinia triticinia*, mature plant resistance, temperature sensitivity, hexaploid wheat.

Introduction

Resistance to leaf rust caused by *Puccinia triticinia* (*P. recondita* Rob. Ex Desm. f. sp. *tritici* Eriks and Henn) has been identified from various germplasm collections and utilized to develop resistant cultivars. Leaf-rust resistance of a large number of wheat cultivars in the Indian sub-continent and elsewhere has been ascribed to many as yet undescribed genes, which are often expressed only in adult plants (Gupta and Saini, 1987; Singh and Gupta, 1991; Shiwani and Saini, 1993; Sawhney, 1998; Kaur *et al.,* 2000). Many leaf-rust resistance genes are known to be sensitive to temperature (Pretorius *et al.,* 1988; Drijepondt and Pretorius, 1991; Statler and Christianson, 1993; Pretorius and Kloppers, 1996). Because wheat is grown under diverse agro-climatic regions throughout the world, the temperature-sensitivity of resistance genes is crucial in their utilization for the development of leaf-rust resistant cultivars having wide adaptability. The present paper describes the temperature sensitivity of the adult plant leaf-rust resistance shown by 16 bread wheat cultivars against race 77-5, the most virulent and frequently identified race on the Indian sub-continent (Nayar *et al.,* 1996).

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Materials and methods

Six Indian leaf-rust resistant cultivars, WL410,

IWP72, HD2204, Mukta, VL421 and WH291, were obtained from the Directorate of Wheat Research, Indian Council of Agricultural Research (ICAR), Karnal, India. Of the ten exotic cultivars studied, eight (Frontana, Pari 73, Flinders, Mentana, Son-Kl-Rend, WW15(R), Chris and Arz) were obtained from the Plant Breeding Institute, University of Sydney, Australia. Cultivar Pavon 76 and the breeding line CIM25 (Kavkaz / 3 / Tobari 66 / Centrifen / Bluebird / 4 / Bolillo) were obtained from the International Maize and Wheat Improvement Centre (CIMMYT), Mexico. The Thatcher near-isogenic leaf- rust resistant lines with the known adult plant leaf-rust resistance genes *Lr12, Lr13, Lr22a, Lr22b, Lr34* and *Lr37* were used for comparison of the infection types and were obtained from the Canadian Department of Agriculture, Canada. Cultivar WL711, developed at the Punjab Agricultural University, Ludhiana, India, was used as an additional source of the adult plant resistance gene *Lr13*. A land race, Agra Local from India, was used as a susceptible control. All these cultivars and the near-isogenic lines were tested for infection types against variant 77-5 of race 77 at 14.5, 20 and 30°C both at the seedling and the adult-plant stage.

For the seedling tests, ten to fifteen seeds of each of the Thatcher near- isogenic lines, cv. WL711 and the test cultivars were sown in 21.5×11.5 cm sized plastic trays containing farm yard manure and sandy loam in equal proportions. In each tray six rows of the experimental material and a seventh row with the susceptible control cv. Agra Local were sown. The seedlings were raised in glasshouses maintained at 20°C. The first leaf of each of the seven-day-old seedlings was inoculated with a urediniospore-talc mixture having a density of 17–18 urediniospores/mm^2 microscopic field area. After inoculation, the seedlings were incubated at 20±1°C in the dark at 100% relative humidity for 16 h. The trays were then moved to glasshouse benches maintained at 14.5, 20 and 30°C. The experimental work was started in January 2001 and completed in February 2001. The average number of sunshine hours during these months was 7.45 h.

To obtain adult plants, the seeds of each cultivar and near-isogenic line were sown in mid-September in 45-cm diameter pots filled with a mixture of farmyard manure and sandy loam (1:1). Four seeds each of four cultivars/lines were sown in clockwise direction at four perpendicular diameter points of each pot. Four seeds of the susceptible cultivar Agra Local were sown in the centre of each pot. Thinning of seedlings was done at the two-leaf stage so that only one plant per cultivar or near-isogenic line grew to the flag-leaf stage. The flag leaves of most of the lines usually emerged in January. The flag leaves of the lines Thatcher+*Lr12*, Thatcher+*Lr13*, Thatcher+*Lr22a*, Thatcher+*Lr22b*, Thatcher+*Lr34* and Thatcher+*Lr37* emerged late. Therefore, these six lines were exposed to light (36 K lux) for six hours a day till they started showing flag leaves. Three flag leaves per plant were inoculated with the urediniospore-talc mixture of race 77-5 and the inoculated plants were incubated in the dark for 24 hours at 20±1°C and then moved to glasshouses maintained at 14.5, 20 and 30°C. The experiment was carried out in two replications.

The observations on infection types were often recorded 14 days after inoculation of seedlings or adult plant grown at standard test conditions of 20°C. Because the seedlings and adult plants were also grown at 14.5 and 30°C, which were lower and higher than normal temperatures for development of leaf-rust, the infection types at 14.5 and 30°C were recorded 21 days and 12 days after inoculation respectively, following the method described by Stakman *et al.* (1962). To determine the response of the seedlings and adult plants, the sporulating pustules without necrosis or chlorosis along the leaf margins were scored 3 and regarded as susceptible. Large profusely sporulating pustules were scored 3$^+$. Infection types 3 and 3$^+$ on the same leaf were recorded as 33$^+$. Necrotic lesions indicated a hypersensitive response, which was evidence of race-specific resistance. Infection type 0; was characterized by only 3–4 necrotic spots, infection type ; by a large number of necrotic spots on the leaf, and infection type 1 by non-sporulating pinhead pustules surrounded by a large and sharp necrotic area. Large non-sporulating pustules surrounded by small areas of necrosis and chlorosis were scored as 2. Intermediate infection types were recorded as + or -, variants of the standard infection types. More than one type of uredia, including the susceptible types 3 or 3$^+$, distributed randomly on a leaf, were scored as X.

Results and discussion

The seedling and adult plant infection types of the test cultivars and Thatcher near-isogenic lines against race 77-5 at three temperatures are given in Table 1. The seedlings of all the cultivars and near-isogenic lines were susceptible 3 to 3$^+$ at all three temperatures. The infection types of the wheats cv. Frontana, CIM25, Pavon 76 and Pari 73 ranged from ;1$^+$2$^-$ to X at 14.5°C, and these wheats expressed susceptible infection types at 20 and 30°C. The infection types on cv. Flinders changed from 2 at 14.5°C to 2$^+$3 at 20°C, which changed to 33$^+$ (susceptible) when the temperature rose to 30°C. The cultivars Mentana, WL410, IWP72, HD2204 and Son-Kl-Rend developed infection types 2$^-$ to X at the adult plant stage at 20°C. The infection types on these five wheats were 3 to 33$^+$ at 14.5 and 30°C. The infection types on cv. Chris changed from 2$^+$3 at 20°C to ;1 at 30°C, that on cv. Arz from 2$^+$3$^-$ at 20°C to 1^{++}2$^-$ at 30°C.

Table 1. Seedling and adult plant infection types of wheat cultivars and Thatcher near-isogenic lines when infected with race 77-5 at three temperatures. Cultivars/lines are grouped following the temperature at which adult plant resistance was shown.

Cultivar/line	Infection type[a]					
	14.5°C		20°C		30°C	
	Seedling	Adult plant	Seedling	Adult Plant	Seedling	Adult plant
Frontana	33$^+$	2$^+$	33$^+$	3$^-$	33$^+$	33$^+$
CIM25	33$^+$	;1$^+$2$^-$	33$^+$	3$^-$	33$^+$	33$^+$
Pavon 76	3	X	33$^+$	33$^+$	33$^+$	33$^+$
Pari 73	3	X	33$^+$	33$^+$	3	33$^+$
Flinders	33$^+$	2	33$^+$	2$^+$3	33$^+$	33$^+$
Mentana	3	33$^+$	33$^+$	2$^+$3$^-$	33$^+$	33$^+$
WL410	3	33$^+$	33$^+$	2$^+$3	33$^+$	33$^+$
IWP72	33$^+$	33$^+$	33$^+$	2$^-$	33$^+$	33$^+$
HD2204	3	33$^+$	33$^+$	X	33$^+$	33$^+$
Son-Kl-Rend	3	3	33$^+$	2	33$^+$	33$^+$
Thacher + *Lr22a*	33$^+$	33$^+$	33$^+$	;1	33$^+$	33$^+$
Thacher + *Lr37*	33$^+$	33$^+$	33$^+$	X	33$^+$	33$^+$
Chris	33$^+$	3	33$^+$	2$^+$3	33$^+$	;1
Arz	3	3	33$^+$	2$^+$3$^-$	33$^+$	;1^{++}2$^-$
Mukta	3	33$^+$	33$^+$	33$^+$	3	;1^{++}2
WW15(R)	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$	1$^+$2
VL421	3	33$^+$	33$^+$	3	33$^+$	1$^+$2
WH291	3	;12	33$^+$	;1$^-$	33$^+$	1$^+$
Thacher + *Lr12*	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$
Thacher + *Lr13*	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$
Thacher + *Lr22b*	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$
Thacher + *Lr34*	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$
WL711 (*Lr13*)	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$
Agra Local	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$	33$^+$

[a] According to Stakman *et al.* (1962). See Materials and Methods for the explanation of the numbers and symbols representing infection types.

The cultivars Mukta, WW15(R) and VL421 showed low infection types (;1^{++}2 to 1^{+}2) only at 30°C. The seedlings and adult plants of these wheats developed high infection types (3 to 33^{+}) at 14.5 and 20°C. These result suggest that cv. Frontana, CIM25, Pavon 76, Pari 73 and Flinders have low temperature adult plant resistance (LTAP), while cv. Mukta, WW15(R), VL421, Chris and Arz have high temperature adult plant resistance (HTAP). Cultivar WH291 appears to have adult plant resistance gene(s) that remain effective at all three temperatures. The infection pattern of cv. Mentana, WL410, IWP72, HD2204 and Son-Kl-Rend was similar to that of the known adult plant resistance genes *Lr22a* and *Lr37*. Although these five wheats are not likely to carry these genes, their adult plant resistance was similar in expression to that of the genes expressed only at 20°C. The remaining Thatcher near-isogenic lines with the known adult plant resistance genes *Lr12*, *Lr13*, *Lr22b* and *Lr34* were susceptible at all three temperatures. The results suggest that the adult plant resistance to leaf-rust race 77-5 is of four types: resistance expressed at 14.5°C (LTAP); resistance expressed at 20°C; resistance expressed at 30°C (HTAP); and resistance that is unaffected by temperature. These results also indicate diversity for adult plant resistance genes, a finding that may be useful for developing wheat cultivars able to withstand pathogen attack over a wide range of agro-climatic conditions.

Effective resistance to leaf rust in wheats grown throughout the world is primarily due to as yet undescribed genes, some of which are reported to be temperature-sensitive (Milus and Line, 1986; Chen *et al.,* 2001). Problems in the accurate identification of such temperature-sensitive genes are sometimes encountered which ultimately affect their transfer to susceptible wheats. Therefore, for successful utilization of such adult plant resistance genes in developing cultivars adapted for wider range of temperature conditions, it is essential to know their temperature sensitivity.

Literature cited

Chen W.Q., Q.M. Qin, Y. Chen, Z.H. Wu, Z.Q. Ma and Q. Liao, 2001. Leaf rust resistance of 40 wheat cultivars in China. *Acta Phytopathologica Sinica* 31, 16–25.

Drijepondt S.C. and Z.A. Pretorius, 1991. Expression of two wheat leaf rust resistance gene combinations involving *Lr34*. *Plant Disease* 75, 526–528.

Gupta A.K. and R.G. Saini, 1987. Frequency and effectiveness of *Lr13* in conferring wheat leaf rust resistance in India. *Current Science* 56, 417–419.

Kaur M., R.G. Saini and P. Kanwal, 2000. Adult plant leaf rust resistance from 111 wheat (*Triticum aestivum* L.) cultivars. *Euphytica* 113, 235–243.

Milus E.A. and R.F. Line, 1986. Number of genes controlling high temperature, adult plant resistance to stripe rust in wheat. *Phytopathology* 76, 93–96.

Nayar S.K., M. Prashar, S.C. Bhardwaj and L.R. Verma, 1996. Distribution pattern of *Puccinia recondita tritici* pathotypes in India during 1990–94. *Indian Journal of Agriculture Sciences* 10, 621–630.

Pretorius Z.A. and F.J. Kloppers, 1996. Seedling and adult plant resistance to leaf rust in the wheat cultivar Tugela. *South African Journal of Plant Soil* 13, 115–119.

Pretorius Z.A., F.H.J. Rijkenberg and R.D. Wilcoxon, 1988. Effects of growth stage, leaf position and temperature on adult-plant resistance of wheat infected by *Puccinia recondita* f. sp. *tritici*. *Plant Pathology* 37, 36–44.

Sawhney R.N., 1998. Genetic analysis of wheat-rust interactions and strategies to breed for durable resistance. *Indian Journal of Genetics and Plant Breeding* 58, 391–416.

Shiwani and R.G. Saini, 1993. Diversity for resistance to leaf rust in *Triticum aestivum*. *Plant Disease* 77, 359–363.

Singh R.P. and A.K. Gupta, 1991. Genes for leaf rust resistance in Indian and Pakistani wheats tested with Mexican pathotypes of *Puccinia recondita* f. sp. *tritici*. *Euphytica* 57, 27–36.

Stakman E.C., D.M. Stewart and W.Q. Loegering, 1962. *Identification of Physiologic Races of* Puccinia graminis *var.* tritici. USDA, *Agricultural Research Services Bulletin* Number E 617 (revised), Washington, DC, USA, 53 pp.

Statler G.D. and T. Christianson, 1993. Temperature studies with wheat leaf rust. *Canadian Journal of Plant Pathology* 15, 97–101.

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