RESEARCH NOTE

Genetics of adult plant stripe rust resistance in CSP44, a selection from Australian wheat

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Abstract

Wheat line CSP44, a selection from an Australian bread wheat cultivar Condor, has shown resistance to stripe rust in India since the last twenty years. Seedlings and adult plants of CSP44 showed susceptible infection types against stripe rust race 46S119 but displayed average terminal disease severity of 2.67 on adult plants against this race as compared to 70.33 of susceptible Indian cultivar, WL711. This suggests the presence of nonhypersensitive adult plant stripe rust resistance in the line CSP44. The evaluation of F_1, F_2 and F_3 generations and F_6 SSD families from the cross of CSP44 with susceptible wheat cultivar WL711 for stripe rust severity indicated that the resistance in CSP44 is based on two genes showing additive effect. One of these two genes is *Yr18* and the second gene is not yet described.

Introduction

Wheat stripe rust (also known as yellow rust) is caused by *Puccinia striiformis* Westend f.sp. *tritici*. It occurs worldwide in high altitudes of the southern and northern areas of temperate zones (Johnson 1988). Yield losses can be considerable, ranging from about 40 per cent to complete destruction of the crop depending upon the growth stage at which the disease attacks. Using diverse genes for resistance against stripe rust disease is the most economical and environmentally safe method to control this disease.

At present 33 genes conferring stripe rust resistance have been identified in wheat and catalogued as *Yr1* through *Yr43* (McIntosh *et al*. 2004). In India, stripe rust research has not received due attention because this disease is localised only to cooler regions of the North Western Plain Zone and the Northern Hill Zone. This disease develops better at temperatures lower than that required for stem rust and leaf rust and therefore, can appear in epidemic proportions in early winter in the northern states of Punjab, Himachal Pradesh and Uttaranchal. Rapid evolution of stripe rust races (Wellings *et al*. 2000) and its ability to cause total crop loss demands further research efforts particularly on genetic diversity for resistance against this disease. Saini *et al*. (2002) reported that a selection, CSP44 from the Australian wheat Condor has shown resistance to stripe rust in multilocation tests in India since 1984. The present report deals with the inheritance of stripe rust resistance of CSP44 against *Yr9* virulent stripe rust race 46S119 (Nayar 1996).

Materials and methods

Wheat line CSP44 (WW80/2*WW15/Kalyansona) was crossed to a stripe rust susceptible cultivar WL711 (S308/Chris//Kalyansona). The F_1 plants were sown off-season 2000 at Directorate of Wheat Research Station, Dalang Maidan, Lahaul and Spiti (H.P.) for advancing the generation. A part of the F_2 seeds thus obtained, were sown at the experimental area of Department of Plant Breeding, Genetics and Biotechnology, Punjab Agricultural University (PAU), Ludhiana and tested for stripe rust reaction during crop season 2000–01. The F_1, F_2 and F_3 generations were simultaneously tested in normal sea-

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son 2001–02 at PAU, Ludhiana. In addition, the F_2 plants obtained from this cross in 2000–01 were also advanced to F_6 generation through single seed descent method to get F_6 families using offseason nursery for generation advancement that were tested for stripe rust reaction in normal season 2002–03. Line CSP44 was also intercrossed with the Thatcher near isogenic line RL6058 (6*Thatcher/PI58548), carrying linked leaf rust and stripe rust resistance genes *Lr34* and *Yr18*. The terminal stripe rust severity was assessed in F_2 generation from this cross to examine the allelic relationship of the stripe rust resistance gene(s) in CSP44 and *Yr18*.

For assessing the infection types, seeds of each of the lines/cultivars were sown in plastic breadbox filled with mixture of sandy loam soil and farmyard manure (1 : 1). First leaf of seven day old seedlings were inoculated with uredospore-talc mixture of race 46S119, incubated for 24 h at 16 ± 4°C at >90% relative humidity and then shifted to the glass house for recording infection types. Inoculum of race 46S119 was procured from DWR, Regional Station, Flowerdale Shimla, which was multiplied on susceptible wheat variety Agra Local.

Adult plants were grown in a glasshouse maintained at 16 ± 8°C, in 25 cm diameter pots filled with a mixture of farmyard manure and sandy loam soil (1 : 1). Sowing was in mid September. Four seeds of four cultivars/lines were sown in clockwise direction in four quarters of a pot. Four seeds of the susceptible cultivar WL711 were sown in the centre of each pot. Thinning of seedlings was made at the two-leaf stage so that one plant per cultivar/line grew up to the flag-leaf stage. The flag leaves of these plants emerged in January. The flag leaves per plant were inoculated with a urediniospore-talc mixture of race 46S119 and inoculated plants were incubated at temperature 16 ± 4°C and >90% relative humidity for 24 h and then shifted to a glasshouse at 16 ± 8°C.

For assessing terminal severity of stripe rust, the material was sown in open experimental field during 3rd week of November in 2 m long paired rows spaced 50 cm apart. Two rows of susceptible cultivars Agra Local and WL711 were sown all around the experimental material and also after every 20 experimental rows. Two rows of each parent were planted on both sides of the F_1 plants. Stripe rust race 46S119 (avirulence/virulence formula P*Yr5*, *Yr10*, *Yr15*, *Yr17*, *Yr24*, *Yr26*, *Yr27*, *YrSp*/p*Yr1*, *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr11*, *Yr12*, *Yr18* at the seedling stage) was used for field inoculations. Stripe rust epidemic was created by hand dusting the urediniospores from infected seedlings on to the dew-covered plants in infector rows early in the morning. Repeated inoculations of the infector rows and the experimental material were also carried out with urediniospores of race 46S119 suspended in water (1 g of rust urediniospores suspended in 10 l of water using two drops of Tween 20). The spray inoculations were done in the evenings with ultralow volume sprayer on alternate days beginning from end of December to mid January till stripe rust appeared on the susceptible cultivars.

The infection types, which assess the hypersensitive type of resistance, were recorded on seedlings and adult plants following the 0, 1–4 scale as described by Wellings *et al*. (1988). The assessment of disease severity in the field was done according to the modified Cobb scale given by Peterson *et al*. (1948). Three observations on terminal disease severity were recorded which started at boot stage. The highest disease severity score was used for genetic analysis. Based on the response pattern, the F_3 families were divided into three categories, *viz*. Resistant (R), Segregating (Segr.) and Susceptible (S). The families showing disease severity between TR to 50 S were recorded as R and the progeny showing uniform level of 60–80 S or more were classified as S. The families with 50 S were presumed to be carrying a single allele from any one of the two genes for stripe rust resistance. On the other hand the families showing disease severity ranging from TR to 80 S were classified as segregating. Chi-square analysis was done for testing the goodness of fit of the genetic ratios.

Results and discussion

Stripe rust resistance at seedling and adult plant stages under controlled conditions

The observations on infection types and stripe rust severity on the lines CSP44, RL6058 and susceptible cultivar WL711 are given in table 1. The line CSP44 developed susceptible infection types (33^+) against race 46S119 at seedling stage as well as at adult plant stage under controlled conditions but it showed low stripe rust severity (TR-20MR) under field conditions. Therefore, it is inferred that this line carries nonhypersensitive type of resistance against stripe rust race 46S119. The line CSP44 and cultivar WL711 showed average coefficient of infec-

Table1. Infection types and disease severity to stripe rust race 46S119.

Line/Cultivar	Seedling stage	Adult plant stage	Disease severity
CSP44	33+	33+	TR–20 MR
RL6058	33+	33+	30–40 S
WL711	33+	33+	60–80 S

tion (ACI) of 2.67 and 70.33, respectively to stripe rust severity against race 46S119 over the years 1999–2003 under high disease incidence conditions. The F_1 plants from the cross of CSP44 with WL711 displayed 20 per cent stripe rust severity. The F_2 generation plants derived from this cross were tested for stripe rust severity over two years (table 2). Out of the 272 F_2 plants studied, 262 were resistant while 10 plants were susceptible during the year 2000–01. The segregation of resistant and susceptible F_2 plants fitted in 15 resistant (R): 1 susceptible (S) ratio. Out of the 240 F_2 plants studied from this cross during the year 2001–02, 222 were resistant while 18 plants were susceptible which also indicate two genes for resistance to stripe rust in CSP44. The F_3 generation from this cross-contained 58 resistant (R), 72 segregating (Segr.) and 11 susceptible (S) families, which segregate in 7R : 8 Segr.: 1 ratio ($c^2 = 0.80$) (table 2), thereby further confirming the two-gene segregation.

The F_6 SSD families were also studied for disease severity. According to Bariana and McIntosh (1995) majority of the lines produced by SSD are homozygous in F_6 generation, hence the ratios of genotypes approach those expected for the gametic rather than zygotic segregation. For example at a single locus the expected ratio of homozygous genotypes among F_2-derived F_6 SSD families would be 1 resistant: 1 susceptible. Similarly the ratios for two-, three-, and four-gene segregation would be 3 : 1, 7 : 1 and 15 : 1, respectively. In the present study, the F_6 SSD families segregated as 3 R : 1 S families ($c^2 = 3.33$) (table 2), which are in accordance with two-gene segregation observed in F_2 generation. Therefore, it is concluded that resistance in line CSP44 is conferred by two stripe rust resistance genes. The F_2 plants and SSD families were grouped into various classes according to their terminal disease severity and plotted against the number of families in each class (figure 1a,b). The frequency distribution of different classes showed continuous variation but skewed towards susceptibility. This skewedness is in accordance with the distribution of four alleles in the population segregating for two genes (1 : 4 : 6 : 4 : 1). The continuous variation indicated additive nature of the stripe rust resistance genes in line CSP44.

The line RL6058 showed average stripe rust severity of 36.67 against race 46S119 over the years 1999–2003 under high disease incidence conditions. In the F_2 generation from the cross of CSP44 with RL6058, no suscepti-

Table 2. Segregation for terminal disease severity in F_2, F_3 and F_6 generations from the crosses of line CSP44 with susceptible cultivar WL711 and Thatcher line RL6058 against stripe rust race 46S119.

Cross		Generation	Disease reaction: Resistant	Segregating	Susceptible	Total	Expected Ratio	c^2
CSP44 × WL711	2000–01*	F_2	262	–	10	272	15 : 1	3.07^{ns}
	2001–02	F_2	222	–	18	240	15 : 1	0.64^{ns}
CSP44 × RL6058	2000–01	F_2	247	–	0	247	–	–
CSP44 × WL711	2001–02*	F_3	58	72	11	141	7 : 8 : 1	0.80^{ns}
	2002–03*	F_6	60	–	30	90	3 : 1	3.33^{ns}

*= Progenies from same cross.

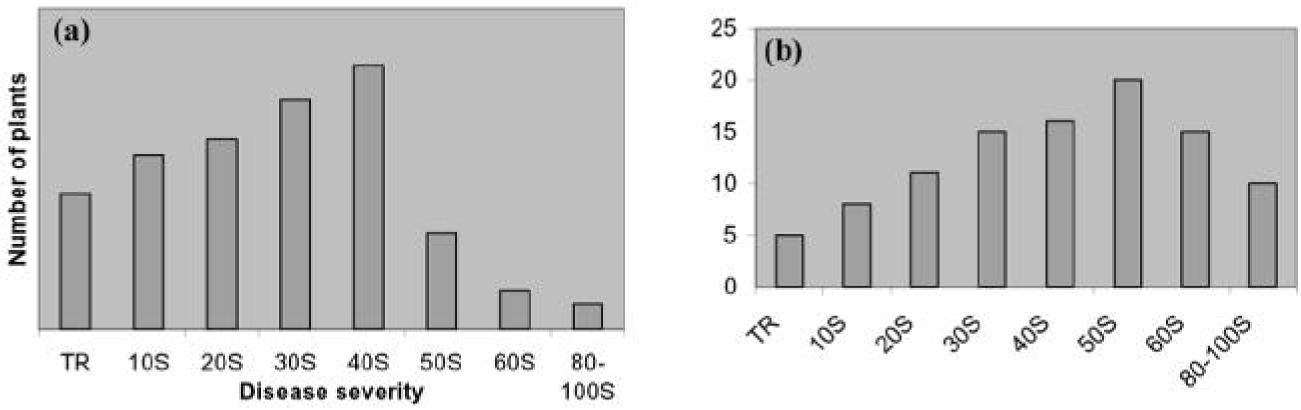

Figure 1. Distribution of F_2 plants (a) and F_6 SSD families (b) in the cross of CSP44 with WL711 for terminal disease severity against race 46S119.

ble plants were observed and all the 247 plants studied were resistant (table 1). It is inferred from these results that one of the stripe rust resistance gene in line CSP44 is allelic to the gene *Yr18* in RL6058. The linked non-hypersensitive adult plant resistance genes *Lr34* and *Yr18* are also linked with a gene for morphological marker, leaf tip necrosis (*Ltn*) (Singh 1992a,b). Because CSP44 shows leaf tip necrosis (LTN score : 3), it further supports that one stripe rust resistance gene in the line CSP44 is *Yr18*. Singh (1992a) and McIntosh *et al*. (1995) also reported that some of the selections of Condor carry *Yr18*. The line CSP44 has shown terminal disease severity ranging from TR to 20 MR over the years whereas the severity on the line RL6058 having the gene *Yr18* has varied between 30 S–40 S. The nonhypersensitive adult plant resistance conferred by the gene *Yr18* is believed to be durable (McIntosh 1992) but the level of resistance conferred by *Yr18* alone is not adequate for commercial exploitation (Singh *et al*. 2001). They also suggested that combination of *Yr18* with 2–4 additional genes could result in adequate levels of resistance suitable for use in most of the environments. The high resistance shown by line CSP44 has resulted from additive effect of *Yr18* and the second as yet undescribed resistance gene in the line CSP44. Similar to the gene *Yr18*, the second gene in CSP44 is also additive in nature, it is likely that combinations of this gene with other such genes will also provide long lasting resistance. Bariana and McIntosh (1995) suggested that a genotype with acceptable levels of adult plant resistance frequently carries at least two or more genes that often act additively. The present report revealed the presence of a new stripe rust resistance gene in CSP44 in addition to *Yr18*, which may also confer long lasting resistance and thus increase diversity for genes conferring durable resistance.

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