SHORT COMMUNICATION

Non-hypersensitive Leaf Rust Resistance of Bread Wheat Cultivar PBW65 Conditioned by Genes Different from *Lr34*

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Abstract: The bread wheat (*Triticum aestivum* L.) cultivar PBW65 has shown hight levels of resistance to the most frequent and highly virulent Indian race 77-5 of leaf rust (*Puccinia triticina*). The infection type and disease severity indicated a non-hypersensitive type of resistance against the race 77-5 in PBW65. The cultivar PBW65 was crossed with the leaf rust susceptible cultivar WL711 to determine the mode of inheritance of the resistance. The segregation for resistant and susceptible plants in the F_2 and F_3 generations revealed, that two genes, each showing additive effects, were likely to confer resistance to leaf rust in PBW65. Intercrossing of PBW65 with Cook (*Lr34*), RL6058 (*Lr34*) and HD2009, possessing a similar resistance level like PBW65, revealed that the genes for leaf rust resistance in PBW65 were non-allelic to Cook (*Lr34*), RL6058 (*Lr34*) as well as to the gene(s) in HD2009. It is concluded that the cultivar PBW65 is a novel source of non-hypersensitive leaf rust resistance.

Keywords: *Puccinia triticina*; allelic test; durable resistance; *Triticum aestivum* L.

Rusts are the most commonly occurring diseases of wheat crop throughout the world (Roelfs *et al.* 1992). The use of resistance genes offers a cost-effective strategy to reduce the losses caused by rusts on wheat. Although race specific genes have provided highly effective resistance, such genes have also selected rust races with the corresponding virulence, resulting in boom and bust cycles. Therefore, breeders are focusing on the identification and incorporation of race non-specific resistance genes. These genes often provide only partial resistance but when used in combination with other genes they can condition highly effective and long-lasting resistance (Singh & Rajaram 2002). The genes conditioning race non-specific resistance are characterized by their inability to evoke a hypersensitive response, slowing of the pathogen growth, partial resistance phenotype, additive nature (Singh *et al.* 2005), optimal expression at the adult plant stage and long-term effectiveness (durability) (McIntosh *et al.* 1995; Messmer *et al.* 2000; Suenaga *et al.* 2001, 2003; Singh *et al.* 2004; Navabi *et al.* 2005; Spielmeyer *et al.* 2005; Bossolini *et al.* 2006). Durability of resistance to leaf rust due to the gene *Lr34* (Dyck 1987; McIntosh 1992; Singh 1992a, b; Singh & Rajaram 1992; Suenaga *et al.* 2003) and *Lr46* (Singh *et al.* 1998; Martinez *et al.* 2001; William *et al.* 2003; Rosewarne *et al.* 2006) has so far been reported to be associated with non-hypersensitive adult plant resistance (APR). Both these genes are also linked to stripe rust resistance (Singh 1992a, b; Singh & Rajaram 1992; Singh *et al.* 1998; Martinez *et al.* 2001; William *et al.* 2003; Suenaga *et al.* 2003; Rosewarne *et al.* 2006). Of these only the *Lr34-Yr18* gene pair is effective in India. Durable adult plant resistance to leaf rust and stripe rust was reported to be quantitatively inherited in the cultivar Cook and based on slow-rusting genes *Lr34* and *Yr18* and the temperature-sensitive stripe rust resistance gene, *YrCK* (Navabi *et al.* 2005). The gene *Lr46* is considered in India as ineffective. Because of the almost complete absence of avirulence to *Lr34* the detection of this gene is based on a morphological marker leaf tip necrosis (Ltn), which is also believed to be tightly linked to this gene (Singh 1992a). Kaur *et al.* (2000) reported many wheats in which Ltn was not present and the non-hypersensitive resistance (NHR) to leaf rust could be ascribed to gene(s) different from *Lr34*. The present paper reports on the genes conferring non-hypersensitive resistance in the Indian cultivar PBW65.

MATERIALS AND METHODS

Cultivar PBW65 (USA225/K816/3/S738// C306/ Kalyansona) was crossed with a leaf rust susceptible cultivar WL711 (S308/Chris/Kalyansona), the reference line RL6058 (6*Thacher/PI58548) for the gene *Lr34,* cultivar Cook (Timgalen/Condor Sib//Condor) and the cultivar HD2009 (Lerma Rajo 64A/Nainari 60), each of these showing non-hypersensitive resistance to leaf rust (Saini & Amita 2000; Khanna *et al* 2005). The landrace Agra Local was used as a susceptible check. The inoculum of leaf rust race 77-5 having virulence to all the known genes for leaf rust resistance originating from bread wheat was kindly supplied by the Head of the Wheat Rust Research Station, Directorate of Wheat Research, Indian Council of Agricultural Research, Flowerdale, Shimla, Himachal Pradesh. The F_1 and segregating F_2, and F_3 populations obtained from crosses were assessed for disease severity in field tests (percentage of leaf area covered with rust) using the modified Cobb scale (Peterson *et al.* 1948). In total 200 individual F_2 plants were harvested to develop their respective F_3 families. The leaf rust scores of only 154 F_2 plants could be obtained during the season because the remaining plants were severely infected with stripe rust.

Table 1. Segregation for leaf rust resistance in field tests against race 77-5 for crosses of cultivar PBW65 with WL711, Cook, RL6058 (*Lr34*) and HD2009

Cross†	Generation F_2					Generation F_3					
	No. of plants					No. of families					
	resistant	susceptible	total	expected ratio	χ^2	homozygous resistant	segregating	homozygous susceptible	total	expected ratio	χ^2
PBW65 (30S) × WL711 (80S-90S)	142	12	154	15:1	0.62	106	84	10	200	7:8:1	6.52*
PBW65 (30S) × Cook (20S)	1337	8	1345	255:1	1.44	F_3 not tested					
PBW65 (30S) × RL6058 (20S)	311	7	318	63:1	0.84	F_3 not tested					
PBW65 (30S) × HD2009 (30S)	307	3	310	255:1	2.65	F_3 not tested					

†Figures in parenthesis give the percent disease severity, *significance at a 5% probability level

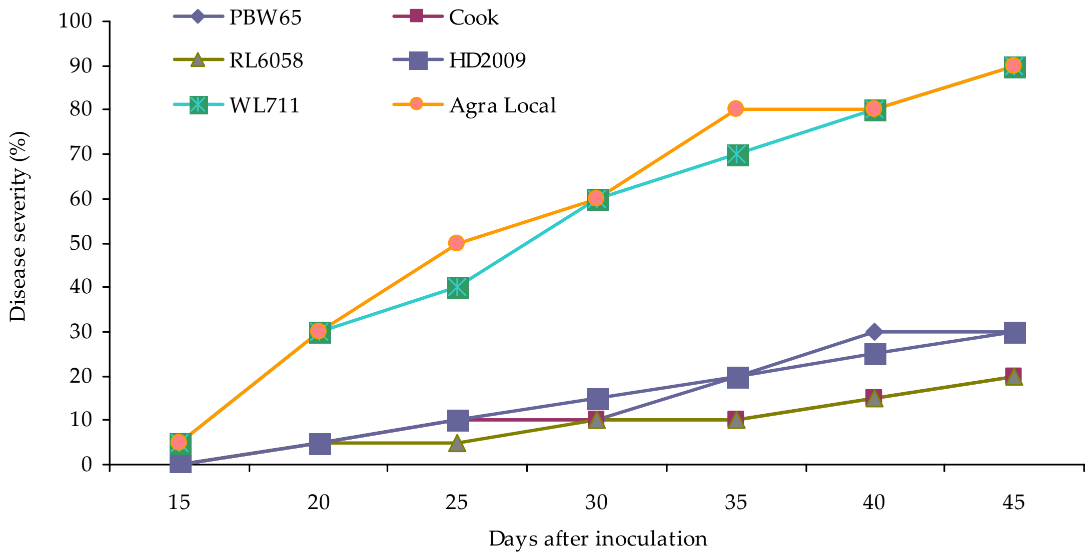

Figure 1. Comparative rate of leaf rust progress in field tests (days after inoculation)

RESULTS

Disease severity of 30S was recorded in the cultivar PBW65, which is comparable to the disease severity observed on the cultivar Cook (20S), line RL6058 (20S) both carrying the gene *Lr34* and cultivar HD2009 (30S) (Table 1). The disease severity in the susceptible cultivars WL711 and Agra Local was estimated to lie between 80S and 90S. The F_1 plants from the cross PBW65 × WL711 showed the percent disease severity of 40S as compared to 80S to 90S recorded in the susceptible parent WL711. The F_2 generation of this cross segregated 142 resistant (R):12 susceptible (S, the score lower than in WL711) which fits to the two gene ratio of 15 (R):1(S) with chi-square = 0.62. The F_3 families from this cross segregated 106 homozygous resistant (HR):84 segregating (Seg):10 homozygous susceptible (HS). The leaf rust severity observations from F_3 families probably also fitted to two gene ratio of 7 (HR):8 (Seg):1 (HS) though the chi-square value (6.52) was significant at a 5% probability level. The high chi-square value could result from misclassification of some segregating F_3 families as resistant because such families contained less than ten plants. The F_2 generations (318 plants) of the cross PBW65 × RL6058 (*Lr34*), 1345 plants of the cross PBW65 × Cook (*Lr34*) and 310 plants from the cross of PBW65 with HD2009 segregated for leaf rust susceptible plants at three gene (63:1), four gene (255:1) and four gene ratios (255:1), respectively. This indicates that gene(s) present in PBW65 are non-allelic to *Lr34* and also to the genes for leaf rust resistance in HD2009. The comparative rate of leaf rust progress of cultivars PBW65, RL6058, Cook, HD2009, WL711 and Agra Local is shown in Figure 1.

DISCUSSION

The leaf tip necrosis (Ltn) considered as a phenotypic marker for detecting the leaf rust resistance gene *Lr34* was not evident in the cultivar PBW65. The Ltn associated with *Lr34/Yr18* is quantitatively expressed and it shows a variable expression in different genetic backgrounds when tested under different environmental conditions (Messmer *et al.* 2000; Rosewarne *et al.* 2006). Owing to the absence of Ltn in cultivar PBW65 it can be suggested that the cultivar PBW65 does not carry the gene *Lr34*. The F_1 generation of the cross between PBW65 and WL711 showed the percent leaf rust severity of 40S, which is higher than in the resistant parent (30S) indicating that the loss of alleles for resistance in the F_1 could increase susceptibility. This is a characteristic of genes showing additive effects. Therefore, based on inheritance studies and the F_1 reaction it can be concluded that two genes conferring the leaf rust resistance of cultivar PBW65 to race 77-5 are additive in nature. Pandher (1993) also reported more than one gene with small cumulative effect governing resistance to leaf rust in cultivar PBW65. Because PBW65 provides protection from leaf rust that is similar to cultivar HD2009 and the gene *Lr34* in Cook and RL6058 (Figure 1) it could be used as a diverse source of non-hypersensitive leaf rust resistance genes. Enhanced levels of resistance, close to almost near immunity can be obtained when genes from PBW65 are used in combination with other diverse genes, particularly *Lr34*. Those genes can further be utilized when used in different backcrossing programmes for their transfer in popular wheat varieties to broaden the genetic base for defence against the leaf rust fungus.

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