Resistance to Rusts in Bangladeshi Wheat (*Triticum aestivum* L.)

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Abstract: Leaf rust caused by *Puccinia triticina* is the most important disease among the three rusts of wheat in Bangladesh. The disease occurs in all wheat growing areas of the country with varying degrees of severity. Stem rust caused by *P. graminis* f.sp. *tritici* was last observed during the mid 1980s, while yellow rust caused by *P. striiformis* f.sp. *tritici* occurs occasionally in the north-western region, where a relatively cooler climate prevails during the winter months. None of the rusts has yet reached an epidemic level, but damaging epidemics may occur in future, particularly if a virulent race develops or is introduced. The genes conferring rust resistance in the breeding lines and wheat varieties released in Bangladesh were investigated at CIMMYT-Mexico and DWR-India. The resistance genes *Lr1*, *Lr3*, *Lr10*, *Lr13*, *Lr23* and *Lr26*, *Sr2*, *Sr5*, *Sr7b*, *Sr8b*, *Sr9b*, *Sr11* and *Sr31*; and *Yr2KS* and *Yr9* were found. An adult plant slow rusting resistance gene *Lr34* was also identified in some of the breeding lines and varieties based on the presence of clear leaf tip necrosis under field conditions. Considering the possible risk of migration of the devastating Ug99 race of stem rust into the Indo-Pak subcontinent, the Bangladeshi wheat lines and cultivars are being regularly sent to KARI in Kenya for testing their resistance against this race. The resistant lines have been included in multi-location yield trials and multiplied for future use in order to mitigate the threat of Ug99. The resistant lines have also been included in crossing schemes to develop genetic diversity of rust resistance.

Keywords: Bangladesh; resistance genes; rusts; wheat

Wheat (*Triticum aestivum* L.), being the second major cereal crop after rice, contributes to food security, human nutrition and livelihood improvement of resource poor farmers in Bangladesh. The current annual consumption requirement of wheat in the country is about 3.6 mil t and a third to half of this need is met through local production. There is an increasing shortfall of 2.0–2.5 mil t per year, which is met through imports at a rising cost of approximately US$ 500 mil to 700 mil a year. The rate of increase in wheat consumption is about 3% per year, and by 2020 the annual wheat requirement of the country will be more than 4.0 mil t. CIMMYT's involvement in the wheat research and development activities in Bangladesh led to a spectacular increase in the wheat area and production during the 1980s and 1990s by the use of several high yielding varieties, particularly Sonalika in the 1980s and then Kanchan in the 1990s (Waddington *et al.* 2008). Both wheat area and production reached a peak in 1998–1999 when 1.9 mil t of grain were produced on 0.88 mil ha. A gradual decline in area and production was observed thereafter largely because of the increasing susceptibility of Kanchan to diseases, particularly bipolaris leaf blight (spot blotch), and also due to competition with other more profitable winter crops. However, wheat yields have increased in recent years by the gradual replacement of the susceptible variety Kanchan with new varieties such as Shatabdi, Bijoy and Prodip, often producing 20% more yield than Kanchan.

Diseases, particularly rusts, are one of the major constraints to sustainable production of wheat worldwide (Saari & Prescott 1985). In Bangladesh, leaf rust caused by *Puccinia triticina* Eriks., is the second most important disease of wheat after bipolaris leaf blight caused by *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem. Under the agro-climatic conditions of Bangladesh, the incidence of leaf rust is usually observed in mid February and its severity increases between mid and late March. Wheat planted at the optimum time either escapes the disease to a large extent, or suffers less compared to those planted late in the crop season. Yield losses due to leaf rust are usually less than 10%, but can be 30% or more depending on the level of susceptibility, environmental conditions and the stage of crop development at the initial stage of infection (Singh *et al.* 2002). Although the losses due to leaf rust in the presently cultivated wheat varieties have not been worked out, they may be significant under favourable conditions for disease development, particularly if infection occurs early in the crop season or a susceptible variety is grown under late sown conditions. Stem rust of wheat caused by *P. graminis* Pers. f.sp. *tritici* Eriks. & E. Henn., used to occur in Bangladesh during the early years of wheat development in the country. However, the disease has not been observed in the country since the mid-1980s, possibly due to the introduction of several resistant varieties. Yellow rust of wheat caused by *P. striiformis* West. f.sp. *tritici* Eriks. & E. Henn., occurs occasionally with low to moderate severity, and is restricted to the north-western districts only, where relatively cooler climates prevail during the winter months. However, both stem and yellow rusts remains a major problem in some of the wheat zones of the world.

Rusts are airborne obligate parasites and difficult to control when a susceptible variety is grown over a large area. The use of resistant varieties having diverse genetic backgrounds is the most effective, economical, environment friendly and dependable option for the management of rust diseases. However, resistance may be broken down due to the appearance of new virulences in the pathogen population. Therefore, regular monitoring of virulence patterns and a continuous search and proper utilization of resistance genes is essential to avoid rust epidemics. With this view, studies were undertaken to analyze the genetic basis of resistance to three rusts in breeding lines and wheat cultivars released in Bangladesh.

MATERIAL AND METHODS

A total of 183 wheat genotypes consisting of crossing block materials, advanced breeding lines and varieties released in Bangladesh were tested for seedling resistance to rusts at CIMMYT in 1994 and at DWR (Directorate of Wheat Research) Shimla, India in 1996 and 2003. At CIMMYT, only leaf rust resistance genes were investigated using Mexican pathotypes, while genes for resistance to all the three rusts were investigated at DWR-Shimla using Indian pathotypes. Four to six seeds of each line/variety were planted in a clump in rectangular plastic/aluminum trays containing FYM and garden soil in a 1:1 ratio. Seedlings of differentials for each of the rusts were raised in separate trays following the same method. Seven to eight day old seedlings of both test genotypes and differential lines were inoculated with 17 pathotypes of leaf rust, 10 of stem rust and 7 of yellow rust in separate greenhouses. The pathotypes of specific rusts were chosen from different virulence groups. The inoculation of seedlings was done by spraying urediospore suspensions prepared in a light-weight mineral oil (Soltrol-170). The inoculated seedlings were incubated in dew chambers for 48 h and then transferred to a greenhouse. The greenhouse temperature was maintained at 22–25°C for leaf and stem rust and 15 ± 2°C for yellow rust. Seedling infection types for leaf and stem rust were recorded 12–15 days after inoculation, and those for yellow rust were noted 16–17 days after inoculation following the modified scale suggested by Nayar *et al.* (2001). The seedling infection types displayed by the test genotypes were compared with those displayed by the differential lines, and the resistance genes present in the test genotypes were postulated by using the gene matching technique (Modawi *et al.* 1985; McVey 1989). The available varieties, advanced lines and breeding materials of wheat have also been evaluated at KARI (Kenya Agricultural Research Institute) in Kenya since 2006 for their reaction against the Ug99 (TTKSK) race of stem rust under epiphytotic condition.

RESULTS AND DISCUSSION

A total of six leaf rust resistance genes viz. *Lr1*, *Lr3*, *Lr10*, *Lr13*, *Lr23* and *Lr26*; seven stem rust resistance genes viz. *Sr2*, *Sr5*, *Sr7b*, *Sr8b*, *Sr9b*, *Sr11* and *Sr31*; and two yellow rust resistance patterns *Yr2KS* and *Yr9* were postulated to be in the 183 wheat genotypes tested. In addition to the named genes, some unidentified factors for resistance (+) were also inferred in most of the lines and varieties. The gene *Lr34*, conferring adult plant slow rusting resistance to leaf rust was identified in some eight genotypes including two cultivars based on the presence of conspicuous leaf tip necrosis. However, only those genes detected in the released varieties are presented in this report (Table 1).

Genes for leaf rust resistance

The most frequent leaf rust resistance gene was *Lr13*, which occurred singly in variety BARI Gom-25 released in 2010 and in combination with other *Lr* genes in seven varieties. Genes *Lr26* and *Lr1* were detected in four and five varieties, respectively (Table 1). Genes *Lr10*, *Lr23* and *Lr3* were postulated in three, two and one variety, respectively. Out of six *Lr* genes, combinations of only two genes were inferred in most of the varieties. Clear leaf tip necrosis, indicated the presence of the adult plant slow leaf rusting resistance gene *Lr34* in Sourav and BARI Gom-26.

The alien gene *Lr26* (1BL/1RS translocation) has been the most widely exploited source of rust resistance in the world for developing high yielding wheat cultivars. The translocated 1RS arm of the rye chromosome is significant because it compensates for the loss of the wheat arm 1BS and also exhibits a heterotic effect on grain yield and adaptation stability across environments (Rajaram *et al*. 1983; Villareal *et al*. 1991, 1997). Depending on the wheat genotypes into which the translocation has been introduced, 1RS may also serve as a selectable marker for genes for high yield on this translocation (Kazman *et al*. 1998). However, at least 10 pathotypes with matching virulence for *Lr26* have been identified in India between 1984 and 2001 (Nayar *et al*. 2001).

Resistance gene *Lr13*, a gene for adult plant resistance was isolated from the Brazilian cultivar Frontana. Use of Frontana in North American wheats led to the evolution of virulences for *Lr13*.

Table 1. Postulated rust resistance genes in the released wheat varieties of Bangladesh

Variety	Year of release	Postulated rust resistance genes		
		Lr	*Sr*	*Yr*
Kanchan	1983	*Lr13+ Lr23*	R[c]	–
Akbar	1983	*Lr10+ Lr13*	–	–
Ananda	1983	*Lr1+ Lr13*	–	–
Barkat	1983	–[a]	*Sr2+ Sr8b+ Sr9b+ Sr11+*	–
Aghrani	1987	*Lr10+ Lr13*	–	–
Protiva	1993	*Lr13+ Lr23*	–	–
Sourav	1998	*Lr1+ Lr26+ Ltn+*[b]	*Sr5+ Sr31+*	*Yr9+*
Gourab	1998	*Lr1+ Lr26+*	*Sr5+ Sr31+*	*Yr9+*
Shatabdi	2000	*Lr1+ Lr13+*	*Sr8b+ Sr9b+ Sr11+*	*Yr2KS*
Sufi	2005	*Lr3+ Lr26*	*Sr2+ Sr31+*	*Yr9+*
Bijoy	2005	–	R	–
Prodip	2005	*Lr1+ Lr26+*	*Sr2+ Sr5+ Sr31+*	*Yr9+*
BARI Gom-25	2010	*Lr13+*	R	–
BARI Gom-26	2010	*Lr10+ Lr13+ Ltn+*	*Sr8b+ Sr9b+ Sr11+*	–

[a]Genes were not postulated; [b]leaf tip necrosis gene *Lr34*; [c]resistant to all Indian pathotypes of stem rust; R – resistant

In contrast to the failure of *Lr13* in North America, it has provided stable resistance in Australia for more than 20 years (McIntosh & Brown 1997). In Indian wheats, *Lr13* was the most commonly identified gene, which became completely ineffective at least when present alone (Sawhney 1995).

The presence of genes *Lr1*, *Lr3*, *Lr10* and *Lr23*, either alone or in association with other genes were detected in Indian, Nepalese, Mexican and some of the American wheat materials (Singh 1993; Nayar *et al*. 2001; Mahto *et al*. 2001; Kolmer 2003). Of the ten *Lr* genes categorized in Indian wheat varieties (Nayar *et al*. 2001), *Lr9* and *Lr24* are very useful, but these genes were not detected in Bangladeshi wheat lines.

The gene *Lr34* was characterized by the presence of leaf tip necrosis in adult plants (Singh 1992). Rubiales and Niks (1995) reported that slow rusting resistance due to *Lr34* was based on a reduced rate of haustorium formation in the early stages of the infection process, in association with little or no plant cell necrosis. This observation indicates a different mechanism for *Lr34*-based slow rusting than hypersensitivity, which is associated with race-specific resistance genes. An increased latent period, reduced uredial size and uredial number, and retarded progress of the disease have been considered the major components of slow rusting resistance (Singh *et al*. 1991). Various CIMMYT wheats that confer excellent adult plant resistance to leaf rust worldwide are known to possess *Lr34* and two or three additional slow rusting genes (Singh & Rajaram 1992).

Genes for stem rust resistance

The varieties Kanchan released in 1983, Bijoy released in 2005 and BARI Gom-25 released in 2010 were found to be resistant to all Indian stem rust pathotypes (Table 1). Gene *Sr31*, which is tightly linked to *Lr26* and *Yr9*, was postulated in four varieties, followed by *Sr5* detected in three varieties. An adult plant stem rust resistance gene *Sr2*, characterized on the basis of mottling pronounced at higher temperatures and sufficient light, and is independent of host pathogen interaction, was detected in Barkat, Sufi and Prodip. The genes *Sr8b*, *Sr9b* and *Sr11* were hypothesized in Barkat, Shatabdi and BARI Gom-26. All these stem rust resistance genes are also present in Indian wheat materials (Nayar *et al.* 2001).

Genes for yellow rust resistance

Two yellow rust resistance patterns *Yr9* and *Yr2KS* were characterized in five varieties (Table 1). Gene *Yr9*, along with some unidentified factors for resistance, was identified in Sourav, Gourab, Sufi and Prodip, while *Yr2KS* was postulated only in Shatabdi. Resistance gene *Yr9* occurs in about 40% of the Indian wheat lines (Bhardwaj *et al.* 1996). The presence of adult plant leaf tip necrosis in Sourav and BARI Gom-26 also indicated the presence of *Yr18* in these cultivars. The genes *Yr2KS* and *Yr18* were also detected in many of the Indian wheat cultivars (Nayar *et al*. 2001).

Resistance to the Ug99 race of stem rust

Under the auspices of CIMMYT and BGRI, wheat materials from Bangladesh are being regularly sent to KARI in Kenya for testing their resistance against the devastating Ug99 race of stem rust. Since 2006, a total of 170 wheat lines of Bangladesh were screened against this race. Among these lines, only a few were found to be resistant, and some showed low to moderate disease severity. Recently BARI Gom-26, previously called BAW-1064, showed moderate levels of disease severity to Ug99, and yielded 10% higher than the popular variety Shatabdi. This has been released as a new variety. Another line, BAW-1051, which also showed a moderate degree of severity to this race of stem rust, is waiting as a candidate variety for release. Two lines BAW-1129 and BAW-1130, showing low disease severity, and some resistant varieties from CIMMYT, were included in the multi-location yield trials, and a few of these were found to be promising in respect of grain yield and other agronomic characters. Seeds of these promising lines, particularly Francolin#1 and the new variety BARI Gom-26 are being multiplied in the research station and farmers' fields toward mitigating the future threat of Ug99. The resistant lines and varieties have also been included in the crossing schemes, and crosses are being made to develop genetic diversity for rust resistance.

Results indicate that the wheat lines of Bangladesh have a narrow genetic base for resistance to rust diseases. Cultivars with a narrow genetic base are unlikely to provide durable resistance and may lead to vulnerability to new races of the pathogen. Although no rust epidemics have so far been observed in Bangladesh, there is no guarantee that they will not appear on a large scale and inflict severe damage in the future, particularly if a virulent race is developed or introduced from outside. This triggers an urgent need to develop genetic diversity of rust resistance utilizing both race-specific and race-nonspecific adult plant slow rusting genes.

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