RESEARCH ARTICLE

Evaluation of wheat (*Triticum aestivum*) germplasm and varieties against stem rust (*Puccinia graminis f. sp. tritici*) pathotype Ug99 and its variants

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ABSTRACT: The studies were undertaken to identify resistance to Ug99 in wheat (*Triticum aestivum L.*) germplasm and popular varieties in East Africa (Kenya and Ethiopia) during 2005-2011. During 2005, out of 22 lines, three genetic stocks, FLW 2 (PBW 343 + Sr24), FLW 6 (HP 1633 + Sr24) and FLW 8 (HI 1077 + Sr25) were found resistant along with HW 1085. Subsequently, 102, 318, 420, 241 and 189 lines consisting of elite advanced lines, along with released varieties were evaluated during 2006, 2008, 2009, 2010 and 2011, respectively, in Kenya and Ethiopia against stem rust (*Puccinia graminis f. sp. tritici*) pathotype Ug99 and its variants. Wheat lines, viz. A-9-30-1, AKDW 4021, DDK 1037, DDK 1038, DDW 14, DL 153-2, GW 1250, HD 2781, HD 3014, HD 4720, HDR 77, HI 8381, HI 8498, HW 234, HW 5211, K 9107, MACS 1967, MACS 2846, MACS 2988, MACS 2998, MACS 3742, MACS 5009, MPO 1215, NI 5439, NIDW 295, PBW 315, PBW 612, PDW 274, PDW 316, PDW 317, WH 147, Sr22, Sr32, Sr35, Sr39, Sr42 and *triticale* varieties TL 2942, TL 2963 and TL 2966, showed resistance to Ug99 and its variants (Ug99TTKS and TTKSK) on evaluation in Kenya and Ethiopia during 2006-2011. During 2010, slow ruster lines for Ug99 resistance were identified based on AUDPC values. These lines may be utilized for improving Ug99 resistance in popular Indian wheat cultivars.

Key words: Wheat, stem rust, Ug99, resistance

Wheat (*Triticum aestivum L.*) is the host for three rusts, viz., leaf or brown rust (*Puccinia triticina*), stripe or yellow rust (*Puccinia striiformis*) and stem or black rust (*Puccinia graminis triticis*) (Roelfs et al., 1992). All these rusts are causing considerable damage but they differ in their distribution pattern in India (Sharma et al., 2001). At present, a number of varieties grown in India are resistant to stem rust against the occurring races. The focus on yellow rust is important for northern India (including the hilly region), while stem or black rust is important in central and peninsular India. However, leaf rust is a problem for all wheat-growing regions in the country. Host resistance, i.e. development of resistant varieties is the main target of the Indian wheat programme (Sharma et al., 2001). Central and Peninsular India are prone to stem rust, while northern hill zone and northern plain zone are less prone to this rust. However, emergence or entry of a new race may pose serious threat to wheat production, especially in the pretext of the changing climatic scenario.

Emergence and spread of Ug99, a new strain of wheat stem rust pathogen, (*Puccinia graminis f.sp. tritici*) in east African countries is particularly alarming, because this pathotype is virulent to most of the stem rust genes conferring resistance in wheat varieties worldwide (Pretorius et al., 2000; CIMMYT, 2005; Jin and Singh, 2006; Stokstad, 2007; Singh et al., 2008, 2011). Stem rust resistance in wheat cultivars with rust resistant gene conferred by Sr31 has been effective worldwide, as well as in India, for more than three decades. However, a new stem rust race, commonly known as Ug99 (TTKS) virulent on Sr31 was first time identified in February 1999 from a nursery grown at Kalangyere Research Station in Uganda, East Africa (Pretorius, 2000). During 2003 and 2004, majority of current Kenyan cultivars and a large portion of CIMMYT wheat germplasm with ‘Sr31’ planted in Kenya became susceptible to this stem rust race, Ug99 pathotype (Wanyera et al., 2006). This variant of *P. graminis f. sp. triticis* has spread in the fields throughout east Africa and has also moved fast from Uganda to Kenya, Ethiopia, Sudan and Yemen. It migrated to Sudan and Yemen in 2006 and was spotted in Iran during 2007 (Singh et al., 2006; GRI, 2007; Nazari et al., 2009). With its spreading nature, it was predicted to reach South-Asia in near future (Singh et al., 2006). It is well-established that breeding for resistance is the best answer to combat such a threat. Njau et al. (2010) identified sources of resistance to Ug99 through evaluation in Kenya. Since, this pathotype is not present in India but could pose a potential threat to wheat cultivation, it was necessary to evaluate Indian germplasm and commonly-grown varieties for their resistance to Ug99 in East Africa (Kenya and Ethiopia) as a part of our preparedness to meet the threat.

MATERIALS AND METHODS

A set of 22 Indian lines/registered genetic stocks were sent to KARI, Njoro, Kenya, during 2005 for evaluation.

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Subsequently 102, 318, 420, 241 and 189 lines consisting of elite advanced lines, along with released varieties were sent in 2006, 2008, 2009, 2010 and 2011, respectively to Kenya (KARI, Njoro, Kenya) and Ethiopia (EARI, Debre Zeit, Ethiopia) for evaluation against stem rust (Puccinia graminis f. sp. tritici) pathotype Ug99 and its variants. All lines were planted in 1m row with a spacing of 23 cm between rows during 2005-2011. Three spreader rows (row-to-row gap of 15 cm) of mixture of susceptible cultivars for Ug99 were planted on four sides of plot. High humidity was maintained for rust development. The infection types (TR, MR, MS, TS and S) were recorded by following McNeal et al. (1971). Stem rust scores were recorded combining disease severity as in modified Cobb’s scale and infection type/s (Peterson et al., 1948). The rust intensities were recorded at equal intervals and Coefficient of Infection (C) was calculated.

RESULTS AND DISCUSSION

The evaluation of 22 Indian lines/registered genetic stocks was accomplished in Kenya during 2005. Though most of the lines were found susceptible, three genetic stocks, viz. FLW 2 (PBW 343 + Sr24), FLW 6 (HP 1633 + Sr24) and FLW 8 (Hi 1077 + Sr25) were found resistant along with HW 1085. Of the two race specific resistance genes against Ug99, (Sr24 and Sr25), one gene Sr24 became ineffective later on to a variant of Ug99 (Njau et al., 2010). During 2006, a set of 102 lines and subsequently 318 entries during 2008, consisting of elite advanced lines, along with released varieties, were sent to Kenya for screening against Ug99. Popular varieties preferred over the fast rusters. The gene Sr31 is also present. The most common gene in these genotypes evaluated at Kenya was done based on AUDPC values (Table 3). The genotypes with similar terminal score but with lower AUDPC value are the true slow rusters (AUDPC values of 101 - 200) and are preferred over the fast rusters.

Rust resistance genes: Based on response of differential lines, Ug99 is reported to be avirulent on Sr 21, 22, 24, 25, 26, 27, 29, 32, 33, 34, 35, 36, 39, 40, 42 and 43, while it was found virulent to Sr 5, 6, 7b, 8a, 8b, 9b, 9e, 9g, 11, 15, 17, 30, 31 and 38 (Pretorius et al., 2000). Resistance genes for TTKSK (Ug99), identified in Kenya include, Sr 13, 22, 24, 25, 26, 27, 28, 32, 33, 25, 36, 37, 39, 40, 44 and Sr –Tmp (Jin et al., 2007, Njau et al., 2010). The resistance genes, Sr24 and Sr36, which showed resistance to Ug99 initially, are no longer resistant (Njau et al., 2010; Jin, et al., 2008; Jin et al., 2009). The Indian germplasm evaluated in Kenya and Ethiopia carries several Sr genes alone and in combination. Some of the genes have not been postulated but are supposed to be present. The postulated genes are; Sr 2, 8b, 7b, 9b, 9e, 11, 5, 24, 31, 8a, 13 and 30. The material showing resistance carry, Sr 2+, 11+, 2+11+, 9e+, 2+8b+, 2+9e+, 11+, 2+9e+, 7b+ (DWR, 2011; DWR, 2012). The plus sign (+) indicates that some more unknown gene or genes (not deciphered) is/are also present. The most common gene in these resistant lines is Sr2 which is the durable gene and should be preferred, alongwith other genes. The gene Sr31 is the most effective gene against the Indian races of stem rust, but is susceptible to Ug99 and its variants.
Table 1. Phenotypic evaluation of Indian wheat germplasm against Ug99 in Kenya and Ethiopia for three crop seasons (2009-2011)

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<tr>
<th>Coefficient of Infection (ACI)</th>
<th>Genotypes</th>
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<tbody>
<tr>
<td>Wheat genotypes resistant to Ug99 in Kenya and Ethiopia (ACI ranging 0-10)</td>
<td>A-9-30-1, AKDW 4021, DDK 1037, DDK 1038, DDW 14, DL 153-2, GW 1250, HD 2781, HD 3014, HD 4720, HDR 77, HI 8381, HI 8498, HUW 234, K 9107, MACS 1967, MACS 2846, MACS 2988, MACS 2998, MACS 3742, MACS 5009, MPO 1215, WH 147, NW 940, NI 5439, NI 825, PBW 315, PBW 612, PDW 274, PDW 316, PDW 317, RSP 561, Sr22, Sr32, Sr35, Sr39, Sr42, TL 2942, TL 2963 and TL 2966</td>
</tr>
<tr>
<td>Wheat genotypes resistant to Ug99 in Kenya and Ethiopia (ACI ranging 10.1-15.0)</td>
<td>HUW 234, K 508, AKAW 4627, AKDW 2997-16, COW (W) 1, DDK 1001, DDK 1009, DDK 1025, DWR 1006, GW 1139, GW 1251, GW 406, HD 4671, HUW 464, K 0710, PL 172, PL 419, RD 2503, Sr27, UPD 85 and WHD 943</td>
</tr>
<tr>
<td>Wheat genotypes resistant to Ug99 in Kenya and Ethiopia (ACI ranging 15.1-20.0)</td>
<td>HS 512, J 858, Jagriti, K 409 and MACS 2971</td>
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<tr>
<td>Wheat genotypes resistant to Ug99 in Kenya (ACI ranging 0-10)</td>
<td>GW 1245, HD 2985, HI 8881, HPW 289, HS 2955, NIAW 34, PDW 233, Sonalika, UAS 318 and UAS 419</td>
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<tr>
<td>Wheat genotypes resistant to Ug99 in Kenya (ACI ranging 10.1-15.0)</td>
<td>CBW 38, DDW 15, GW 391, HPW 296, HPW 297, HPW 315, Kharchia 65, KRL 250, KRL 251, Lok-1, NW 2036, PBW 610, PDW 291, UP 2338, WH 1080 and WH 896</td>
</tr>
<tr>
<td>Wheat genotypes resistant to Ug99 in Ethiopia (ACI ranging 0-10)</td>
<td>MP 3288, NIAW 1415, DBW 62, DL 788-2, DWR 28, GW 173, GW 366, GW 388, GW 396, GW 496, HBL 3616, HD 2285, HD 2329, HD 2664, HD 2898, HD 2983, HD 2987, HD 3007, HD 4672, HI 1500, HI 1531, HI 1544, HI 1563, HI 454, HS 512, HUW 488, J 858, Jagriti, K 0803, K 329, K 409, K 551, K 603, K 9533, MACS 2971, MACS 3125, MACS 6145, MACS 6273, MP 1142, MP 1913, MP 4010, MP 1220, MPO 1226, MPO 1395, NW 1012, NW 2038, NW 387, PBW 620, PBW 623, PBW 628, PL 462, PL 751, RAJ 1555, RAJ 3777, RAJ 4037, RAJ 4120, RAJ 8560, RD 2035, RD 2052, RD 2508, RD 2552, RD 2592, Sr 13, Sujata, UAS 415, UP 2526, UP 2565, UP 2572, UP 262, VL 924 and VL 925</td>
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<tr>
<td>Wheat genotypes resistant to Ug99 at Ethiopia (ACI ranging 10.1-15.0)</td>
<td>HUW 510, UP 2771 and VL 926</td>
</tr>
<tr>
<td>Wheat genotypes resistant to Ug99 at Ethiopia (ACI ranging 15.1-20.0)</td>
<td>DBW 49, DDW 15, GW 1245, HD 2382, HD 2428, HD 2719, HD 2982, HI 1416, HI 1479, HI 8881, HI 8893, HPW 309, HS 365, HS 521, HUW 626, HW 1043, HW 2004, K 0607, K 0707, K 0708, K 0716, KRL 19, KRL 240, KRL 251, Lok-1, MP 1224, MP 3224, NW 1014, NW 1067, NW 2036, NW 4035, PBW 138, PBW 154, PBW 509, PBW 550, PBW 613, PBW 617, PDW 291, RAJ 3077, RAJ 4083, RAJ 4178, UAS 419, UAS 914, VL 914 and VL 933</td>
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<td>Entries showing resistance during three crop seasons</td>
<td>WH 896, HI 8498 (d) and MACS 3742 (d)</td>
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<td>Entries showing resistance during two crop seasons</td>
<td>HS 295, HI 8681, GW 1245 (d), MPO 1215 (d), Lok-1, HI 8680 (d), HD 2781, UAS 415 (d), WH 147, DDK 1009, MACS 2971, HI 8692, DDW 14, HI 8696, HI 8699, GW 1251, GW 1139, HI 8381 and WH 416</td>
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<tr>
<td>Entries showing resistance during 2010 crop season</td>
<td>TL-2942 (c), GW 322 (c), MPO 1215 (I-C), HI 8663 (d) (c), NIW 295 (d) (c), UAS 304 (c), HPW 307, HPW 317, HS 533, TL 2968, TL 2969, VL 944, HI 8703, WHD 946, HD 3028, HUW 639, MACS 3744 (D), HI 8702 (D) and MACS 2998</td>
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Situation in different wheats: In India, three types of wheats are grown, namely *T. aestivum*, *T. durum* and *T. dicoccum*. In addition, triticales are also grown in a limited way in some areas, especially in northern plains. All triticales tested were either immune (TL 2968, TL 2969) or highly resistant (TL 2942, with terminal score of 5R-MR). Pretorius *et al.* (2000) also made similar observations regarding triticales. The CIMMYT triticle lines, most of which carry *Sr27* or *Sr Satu*, are reported to be highly resistant in Njoro, Kenya. Among entries showing resistance during all the three seasons, viz. WH 896, HI 8498 (d) and MACS 3742 (d) were durum genotypes. Further, out of 20 entries showing resistance during both the seasons, 12 were durum genotypes, viz. HI 8681, GW 1245 (d), MPO 1215 (d), HI 8680 (d), UAS 415 (d), HI 8692, DDW 14, HI 8696, HI 8699, GW 1251, GW 1139, and HI 8381. Durum lines generally showed resistance to bread wheat virulent pathotypes 40A and 40-1 among the Indian *Pgt* population also (Mishra *et al.*, 2009).

In India, the germplasm and advanced lines were evaluated against prevalent Indian strains of stem rust under artificially inoculated conditions at hot spot locations in India through All India Coordinated Wheat & Barley Improvement Project (AICW&BIP). No genotype is allowed to be released or recommended for cultivation if it does not fulfill the criteria of resistance to stem rust (and other rusts) fixed for the purpose (Sharma *et al.*, 2001). Evaluation of wheat germplasm against prevalent strains of stem rust has shown that Sr37 is still the most preferred source of resistance to stem rust in India.

Several stem rust resistant genes have been identified for imparting resistance to the new strain Ug99. Some of them, like *Sr25* and *Sr26*, are already present in Indian wheat varieties, while a few others are available in our germplasm and genetic stocks. To counter Ug99, these rust resistant genes have been included in the National Wheat Breeding Programme and lines have been developed. In addition to prevalent pathotypes of...
stem rust, these lines will have resistance to Ug99 too. Nagarajan et al. (2014), however, observed that Pgt-Ug99 lacks pre-eminence to threaten India’s wheat production. If this strain happens to enter India, the Indian programme is well prepared to meet the challenge posed by Ug99 to the Indian wheat crop.

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