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Morphological and Disease Reaction Studies in Triticale x Wheat Derived Stable Lines

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Abstract—*Yellow (stripe) and brown (leaf) rust diseases pose a major problem in the hills and foot hill areas, respectively. Triticale (x Triticosecale) has been used as bridge specie to transfer rye (Secale cereale) genes into wheat conferring disease resistance and agronomic traits of importance. Therefore, triticale x wheat crosses offers to generate elite breeding material for further use in the gene pool. The present investigation involved the agro-morphological characterization of the advanced breeding lines (BC_1F_7 and F_7) derived from triticale x wheat crosses and disease resistance screening against the prevalent yellow rust races viz., 78S (84) and 46S (119) and leaf rust races viz., 121R-1(77-5) and 21R55 (104-2). Most of the stable lines diversed with regard to spike type, maturity, plant height and showed variable resistance against both the races of yellow as well as leaf rust. The advanced lines also possessed rye chromosome introgression as evident from the plant type.*

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the staple food crop grown globally on about 219 million hectares worldwide with a production of 720 million tons (FAOSTAT 2015) [1]. The developing countries contribute approximately half of the wheat production of the world. It provides approximately one-fifth of the total nutritional input for all humans. Post green revolution in the 1960's, the Indian wheat production increased rapidly with the introduction of the semi-dwarf wheat varieties and continuous development of fertilizer responsive cultivars has further led to quantum jump in yields. At present, wheat yield has almost reached a plateau and another striking breakthrough is required in order to meet the ever-increasing food demand of the nation. In the hill states of the country, wheat is generally grown under diverse and rainfed conditions. Thus, drought becomes the major constraint, followed by cold stress and susceptibility to various biotic (rusts and powdery mildew) & abiotic (cold) stresses, which drastically reduce the production of wheat in these areas. The wheat rusts have historically been one of the major biotic production constraints both in Asia and rest of the world (Singh and Rajaram 1991) [2]. The fungal pathogens have significantly reduced yield and quality especially affecting kernel weight by restricting photosynthesis on leaves.

Stripe (yellow) rust of wheat, caused by *Puccinia striiformis* Westend. f. sp. *tritici* is important disease of wheat worldwide. This is mainly due to the pathogen's ability to mutate and multiply rapidly and to use its air-borne dispersal mechanism from one field to another and even over long distances (Singh et al. 2005) [3]. Therefore, use of chemicals is neither economical nor feasible on large scale. As per McIntosh et al. (1995), the crop losses may go upto 70 per cent [4]. The two yellow rust pathotypes 46S119 and 78S84 generally occur during the crop season. Among the wheat rusts, leaf rust (*Puccinia recondita* f. sp. *tritici*) is also a serious production hazard in wheat all over the world. Recent studies have shown that leaf rust severity has increased in the West Asia region and higher virulence and wider adaptation make it more difficult to control accompanied with genetic resistance (Morgounov et al. 2012) [5]. Under Indian conditions, leaf rust pathotypes 121R63-1 and 21R55 are causing major damage to the crop. *P. triticina* populations around the world are characterized by high levels of virulence to the most common leaf rust resistance genes in the regional germplasm. The deployment of rust resistance genes is the most economical means of disease control and is highly recommended in all breeding programs. The breeding objectives must be essentially comprised of the development of high yielding rust resistant varieties. Gene introgression from wheat relatives, wild species and other genera into wheat genome has been well established process to broaden the wheat genetic variability for achieving improvements (Stoyanov 2013) [6]. Disease resistance in combination with desired agronomic traits can be incorporated from certain potential sources like winter wheat and rye (*Secale cereale*).

Triticale (x *Triticosecale* Wittmack), the first man made cereal as a result of cross between wheat (*Triticum aestivum*) and rye (*Secale cereale*), is used as bridging species to accomplish this goal via triticale x wheat hybridization, since it easily hybridizes with wheat. Because of the complement of rye chromosomes, triticales have agronomic attributes that are not found in wheat. Therefore, the triticale gene pool can be incorporated into the wheat background to combine uniform grain quality, production and chapatti-making quality of wheat with disease resistance and nutritional quality of rye. In addition to the conventional approach, doubled haploid technique following wheat x maize (Pratap and Chaudhary 2012) and wheat x *Imperata cylindrica* (Chaudhary et al. 2005) mediated approach in wheat has been successfully used to rapidly recover the doubled haploids in triticale x wheat crosses and also in wheat-rye derivatives (Kishore et al. 2011) [7-9].

2. MATERIALS AND METHODS

2.1 Plant material

The present investigation comprised of 43 advanced breeding lines belonging to BC_1F_7 and F_7 generations used for agro-morphological characterization derived from the crosses of four triticale (ITSN 105/58, TL 2908, TL 2919 and TL 2900) and four wheat (VL 802, RL-14-1, HS 396 and PW 565) genotypes. For rust studies, 51 lines i.e. 25 lines from the existing 43 lines and 26 different lines generated from the same parentage were used. The materials were developed in the experimental fields of Department of Plant Breeding & Genetics, Himachal Pradesh Agricultural University, Palampur and backcrosses were attempted during the offseason at Highland Agricultural Research & Extension Centre, Kukumseri, Lahaul and Spiti. The agro-morphological characterization of forty three advanced breeding lines was done in the experimental fields of Department of Plant Breeding & Genetics, CSKHPKV, Palampur. The parentage of the six triticale x wheat crosses used to generate the advanced lines for morphological and rust studies has been given in Table 1.

Table 1: Parentage of triticale x wheat crosses used to derive advanced lines of wheat

S. No.	Triticale x wheat cross	Parentage
1	TW1	(ITSN105/58 x VL802) x VL 802
2	TW2	(TL 2908 x VL 802) x VL802
3	TW3	ITSN105/58 x VL802
4	TW4	(TL 2900 x RL-14-1) x RL-14-1
5	TW5	TL2908 x HS396
6	TW6	(TL 2919 x PW565) x PW 565

1.2 Seedling test for rust resistance

The material was screened against yellow rust races *viz*., 78S (84) and 46S (119) and leaf rust races *viz*., 121R-1(77-5) and 21R55 (104-2) at IARI Regional Research Station, Shimla (HP). The resistance response of seedlings was evaluated in green house by planting 5 seeds in pots having mixture of soil, peat moss and sand in proportions of 7:5:5. After 10 days of sowing, inoculations with yellow and leaf rust races were conducted by spraying with mixture of spores and talcum powder (in 1:4 proportions). The pots subsequently were placed for 24 hours in a dark moist chamber at 10˚C and then transferred to a greenhouse at 15-18˚C and 16 hour light. Leaf rust severity was recorded by modified Cobb's scale (Peterson et al. 1948) [10]. The stripe rust incidence was recorded according to the method given by McNeal et al. (1971) [11]. Disease reaction was recorded after seven days interval.

3. RESULTS

3.1 Morphological evaluations

All the 43 triticale x wheat derived lines alongwith their morphological traits have been reported in Table 2. The cross TW1 comprised of four lines, of which all were semi dwarf, awned and showed medium maturity except TW1-50, which was early maturing. Line TW1-50 was early maturing and awned. The cross TW2 represented eight lines amongst which, five lines were early maturing and three were medium maturing. In this cross, spikes of five lines were medium compact, medium laxed in two lines and compact in TW2-10. For plant height, six lines were of semi dwarf nature and two lines were tall. Some of the lines of the cross possessed black awned spikes, whereas some were waxy.

Table 2: Morphological evaluations in triticale x wheat derived advanced generations of wheat

S. No.	Line Name	Maturity	Spike type	Plant height	Awned/Awnless
1.	TW1-12	Medium	Lax	Semi dwarf	Awned
2.	TW1-35	-do-	Medium, compact	-do-	-do-
3.	TW1-50	Early	Long, lax	Tall	-do-
4.	TW1-280	Medium	Medium, compact	Semi dwarf	-do-
5.	TW-2-7	Early	Medium, compact, cylindrical	-do-	-do-
6.	TW-2-10	-do-	Compact	-do-	-do-
7.	TW-2-27	-do-	Medium, lax	-do-	Awned (Black)
8.	TW-2-153	-do-	Medium, compact	-do-	Awned
9.	TW-2-160	-do-	Medium, compact	-do-	-do-
10.	TW-2-181	Medium	Medium, lax (waxy)	Tall	-do-
11.	TW-2-184	-do-	Medium (waxy)	Semi dwarf	Awned (Black)

12.	TW-2-186	-do-	Medium, lax (waxy)	Tall	Awned
13.	TW3-5	All triticale type			
14.	TW3-8				
15.	TW3-11				
16.	TW3-24				
17.	TW3-26				
18.	TW3-29				
19.	TW3-41				
20.	TW4-1	Early	Medium, lax	Semi dwarf	Awned (Black)
21.	TW4-2	-do-	-do-	-do-	Awned
22.	TW4-9	-do-	Medium, compact, golden, very hard (waxy)	-do-	-do-
23.	TW4-19	Early	Medium, compact, golden, very hard	Semi dwarf	Awned
24.	TW4-22	Early	Medium, compact, golden (waxy)	Semi dwarf	Awned
25.	TW4-23	-do-	Medium, compact, golden, very hard (waxy)	-do-	-do-
26.	TW4-24	-do-	Medium, compact, golden, hard	-do-	-do-
27.	TW4-43	Medium	Medium, compact, golden black	-do-	-do-
28.	TW4-83	Early	Medium, compact, golden (waxy)	-do-	-do-
29.	TW4-122	Medium	Medium, lax (Black, hard)	-do-	-do-
30.	TW5-1	Early	Medium, lax (hair on lemma and palea)	Tall	-do-
31.	TW5-4	Triticale	Medium, lax	-do-	-do-
32.	TW5-18	Triticale	-do-	-do-	-do-
33.	TW5-31	Triticale	-do-	-do-	-do-
34.	TW5-6	Triticale	-do-	-do-	-do-
35.	TW5-32	Medium	-do-	-do-	-do-
36.	TW6-4	Early	-do-	-do-	Awned (Black)
37.	TW6-7	-do-	-do-	Semi dwarf	Awned
38.	TW6-243	-do-	-do-	-do-	-do-
39.	TW6-245	-do-	-do-	-do-	-do-
40.	TW6-250	-do-	-do-	-do-	Awned (Black)
41.	TW6-261	-do-	-do-	-do-	-do-
42.	TW6-267	-do-	-do-	-do-	-do-
43.	TW6-285	-do-	-do-	-do-	Awned

All the lines representing TW3 cross were of triticale type. Almost all lines of TW4 cross were early maturing except TW4-43 and TW4-122 which showed medium maturity. The spike type in seven lines was medium compact with golden colour, whereas medium lax in three lines. All the lines were associated with semi dwarf plant type and awned spikes. Some lines of the cross showed waxy spikes while others had black awns. The cross TW5 comprised of six lines out of which TW5-1 and TW5-32 showed early and medium maturity, respectively. Rest of the lines resembled triticale phenotypically. Evaluation of eight TW6 lines early maturity with medium lax spikes but some lines had black awns.

3.2 Yellow rust screening

Lines derived from all triticale x wheat derived crosses were screened for disease resistance against yellow rust races 78S (84) and 46S (119) and the results are shown in Table 3. Lines TW1-35, TW1-39 and TW1-50 were susceptible to race 78S (84) but were resistant to race 46S (119). Lines derived from TW2 cross showed varied reaction from susceptible to resistant to both the races. All the lines belonging to cross TW3 were completely resistant to both the races of yellow rust. Lines TW4-2 and TW4-23 of TW4 cross were resistant to the race 78S (84), whereas all lines showed susceptible reaction to the race 46S (119). Three TW5 derived lines were resistant to race 78S (84), whereas all the lines of this cross exhibited susceptibility to the race 46S (119). Most lines of TW6 cross were susceptible to both the races and only few showed resistance. Triticale genotypes TL 2900, TL 2919 and TL 2908 used as maternal parents in these crosses exhibited complete resistance against both the races.

Table 3: Yellow/leaf rust screening in triticale x wheat derived wheat recombinants

Name of the cross	Line No.	Yellow rust race		Leaf rust race	
		78S(84)	46S(119)	121R63-1(77-5)	21R55(104-2)
ITSN 105/58 x VL 802 x VL 802	TW1-35	S	R	S	S
	TW1-39	S	R	S	S
	TW1-50	S	R	S	S

	TW1-63	MS	S	S	S
TL 2908 x VL 802 x VL 802	TW-2-10	MS	S	S	S
	TW-2-25	MS	R	--	S
	TW-2-27	MS	S	S	S
	TW-2-29	MS	--	--	S
	TW-2-30	S	R	S	S
	TW-2-32	S	S	S	S
	TW-2-33	--	S	S	S
	TW-2-35	S	R	S	S
	TW-2-117	MS	S	S	S
	TW-2-119	S	S	S	S
	TW-2-153	S	R	S	S
	TW-2-160	S	S	S	S
	TW-2-181	S	S	S	S
	TW-2-184	S	S	--	S
ITSN 105/58 x VL 802	TW3-2	R	R	S	S
	TW3-3	R	R	S	S
	TW3-5	R	R	S	S
	TW3-11	R	R	S	S
	TW3-14	R	R	S	S
	TW3-23	R	R	--	S
	TW3-24	R	R	S	S
	TW3-26	R	R	S	S
	TW3-29	R	R	S	S
	TW3-38	R	R	S	S
	TW3-41	R	R	S	S
TL 2900 x RL-14-1 x RL-14-1	TW4-1	S	S	S	R
	TW4-2	R	S	S	R
	TW4-23	R	S	S	S
TL 2908 x HS 396	TW5-7	S	S	S	S
	TW5-9	R	S	--	R
	TW5-18	R	S	S	R
	TW5-31	R	S	S	R
	TW5-32	S	S	S	S
	TW5-34	S	S	S	R
	TW5-42	S	S	S	R
TL-2919 x PW 565 x PW 565	TW6-4	R	S	S	R
	TW6-7	S	S	S	R
	TW6-13	S	S	R	R
	TW6-31	--	R	R	--
	TW6-109	--	R	R	--
	TW6-145	R	S	R	--
	TW6-237	R	S	S	--
	TW6-243	S	S	S	S
	TW6-250	S	R	S	R
	TW6-261	--	S	S	R
	TW6-267	S	S	S	S
	TW6-285	S	S	R	R
Triticale Parents	TL 2900	R	R	R	R
	TL 2919	R	R	R	R
	TL 2908	R	R	R	R

R- Resistant, S- Susceptible, MS- Moderately Susceptible, -- No germination

3.3 Leaf rust screening

Triticale x wheat derived lines were screened for their disease resistance potential against two leaf rust races *viz*., 121R63-1(77-5) and 21R55 (104-2) (Table 3). The severity was more as compared to yellow rust as all the lines of TW1, TW2 and TW3 crosses were found to be susceptible to both the races of leaf rust. The remaining crosses TW4, TW5 and TW6 showed limited number of lines expressing resistance to both the leaf rust races. All the three triticale genotypes were resistant against both the leaf rust races.

4. DISCUSSION

4.1 Morphological studies

The advanced lines derived from triticale x wheat crosses exhibited variable morphological traits. Plant height along with spike type are important traits conferring good yield in wheat crop. Triticale x wheat hybridization, therefore, represents a suitable approach to introgress useful rye genes through wheat-rye translocations, especially 1BL.1RS in the wheat genetic background using triticale as bridge specie. Besides important agronomic traits, the rye chromatin in this translocation has been reported to enhance the yield of wheat varieties upto 10 per cent (Carver and Rayburn 1994) [12]. The triticale x wheat hybrids under study exhibited self fertility in the advanced generations. It is in agreement with the earlier studies of self fertility in interspecific hybrids between triticale and common wheat (Hills et al. 2007) [13]. The advanced lines were morphologically similar to the backcrossed wheat ideotype also indicating the presence of rye chromatin. Earlier significant studies on bread wheat have also rendered useful traits of rye to 1BL.1RS translocation (Villareal et al. 1998) [14].

Gill et al. (2010) in a study of 31 morphologically uniform looking lines belonging to BC_1F_4, BC_2F_3, F_4 and F_5 families obtained from the crosses of four triticale and five wheat showed reversion towards the wheat parent [15]. The hybrids were slightly bigger than both parents, had more spikelets per spike and tillered more profusely. Both fixable and non-fixable effects were reported to be responsible for plant height and spike length (Bajpai and Mishra 1986) [16]. The stable lines also showed variable maturity periods belonging to early and medium maturing groups. Early maturing genotypes makes a good selection in the hill topography due to rainfed cultivation which can go late winters in December, whereas the medium maturing are considered for timely sown conditions. Semi-dwarf genotypes are preferred over the tall ones for their lodging resistance. The material showed both semi dwarf and tall genotypes in equal proportions and therefore selection opportunity exists for both types. Mittal and Sethi (2005) found plant height and grains/spike important traits for phenotypic selection in hexaploid triticale x wheat lines [17]. Similar observations recorded in the present investigation substantiate the earlier research for morphological traits.

4.2 Yellow/leaf rust screening

Yield losses caused by leaf rust epidemic are estimated at around 40 per cent and due to yellow rust epidemics can be as great as 100 per cent. Resistance breeding with defined genes for slow rusting is a feasible way to overcome losses by rust fungus. In India, most of the pathotypes of *Puccinia* species on wheat originate through mutation, parasexuality and in some cases especially yellow rust get introduced from Western Asia. Yellow rust races *viz.*, 78S (84) and 46S (119) by far remains the most devastating in terms of crop losses. Following a widespread cultivation of varieties with 1B/1R translocations, pathotype designated as 46S119 having virulence for Yr and Yr 27 has also been found susceptible (Prashar 2007) [18]. Zhang et al. (2001) reported moderately resistant reactions for yellow rust in a doubled haploid line obtained from a cross between hexaploid triticale and Chinese Spring wheat [19]. Therefore, the lines displaying resistant to moderately resistant reaction are of great importance to achieve durable resistance to all rusts. The advanced lines also showed reactions from immunity to extreme susceptibility against stripe rust including differential response to the pathotypes (Eshan-ul-Haq et al. 2003) [20]. Resistance to yellow rust was revealed in many wheat-rye derivatives containing 1BL.1RS translocated chromosomes (Conner et al. 2007) [21]. Similarly, yellow rust in advance breeding lines was also revealed under controlled greenhouse conditions (Bux et al. 2012) [22].

Leaf rust races *viz.*, 121R63-1(77-5) and 21R55 (104-2) are responsible for causing imminent losses during the crop season. Many useful resistance genes like *Lr9*, *Lr19* and *Lr28* have been rendered susceptible (Bhardwaj 2010) [23]. Wheat genotypes possessing 1BL.1RS translocation had differential disease reaction to leaf rust fungus and genotypes carrying 1BL.1RS translocation appeared more tolerant to leaf rust (Kumar et al. 2003, Dimitrijevic et al. 2008) [24-25]. In one of the studies though most of the lines were susceptible to leaf rust but equal number were immune and exhibited durable resistance (Sohail et al. 2013) [26]. The above results are in agreement with the present study where susceptible leaf rust reaction has also been observed in most of the advanced lines.

The present study in triticale x wheat advanced lines has resulted in the identification of agronomically superior derivatives having a fair degree of resistance to yellow rust, though most lines were susceptible to leaf rust races; the appearance of normal infection type shows that the available advanced lines are a good genetic stock. Based on disease response it can be concluded that advanced lines have durable resistance against all rusts and this germplasm enriched with diverse sources of resistance can be further utilized through gene pyramiding to develop resistant and high yielding wheat cultivars. Since a wide genetic diversity in rye germplasm exists worldwide, it is important to utilize this variation for future wheat breeding by developing new 1BL.1RS translocations and widen the triticale genepool. However, more studies to evaluate these elite materials for slow rusting components needs to be investigated.

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