Pak. J. Bot., 41(3): 1463-1475, 2009.

RESISTANCE POTENTIAL OF WHEAT GERMPLASM (*TRITICUM AESTIVUM* L.) AGAINST STRIPE RUST DISEASE UNDER RAINFED CLIMATE OF PAKISTAN

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Abstract

Enduring resistance based on partial resistance is very noteworthy and successful way to combat against the stripe rust dilemma (*Puccinia striiformis* West. *tritici*) in wheat crop. For this purpose, field-based screening to evaluate partial resistance is very important for the plant breeders of developing countries, who usually handle hundreds of lines at a time. A two years study was conducted during 2005-2007 to determine variability for field based-partial resistance against stripe rust among 188 wheat breeding lines grown at the experimental area of the PMAS - Arid Agriculture University, Rawalpindi, along with *Morocco* as susceptible check. The wheat lines and commercial varieties were tested in the field under natural climatic conditions of arid zone of Pakistan. Average Coefficient of Infection (ACI) and Relative Resistance Index (RRI) values of two-year trial showed that out of 188 cultivars, 150 responded with RRI value $\geq 7 \leq 9$ and were found in the desirable range; 28 cultivars were included among the acceptable range having RRI value $\geq 5 \leq 7$. However, only 10 cultivars showed RRI value <5 and were placed under undesirable range.

Introduction

Among plant diseases, stripe / yellow rust inflicted by *Puccinia striiformis* is a wheat crop foliar disease of significant importance. The disease is known to cause heavy economic losses around the globe. The intensity of loss primarily depends upon the resistance level of the germplasm. In case of highly susceptible varieties, losses may escalate as high as 80 % (Eversmeyer & Browder 1974; Kolmer, 1996; Beard *et al*., 2007). Severe infection causes shriveling of grains though the grain is sound otherwise. Due to the phenomenon, physical and biochemical qualitative characteristics of wheat such as test weight, bulk density, falling number, carbohydrate and fiber contents are negatively influenced. Besides grains become stunted, which impair market value and weight of grains. To coup with these problems plant pathologists and the farmers had been trying to sow germplasm from different sources in quest to escape losses caused by this disease. Main emphasis had been to exploit indigenous resources for developing genetically diverse wheat varieties suitable for varying temperatures, humidity levels, soil characteristics, slopes and altitudes (Feyissa *et al*., 2005). The breeding programmes for combating stripe rust disease have been reliant on the vital genes as well as to respond towards substantial cut down of resistance because the fungus has the ability to mutate and overcome varietal resistance. Combined use of the significant genes that, independently, have previously been 'matched' with the pathogen may provide another level of resistance. But this too is potentially susceptible to breakdown and invariably short-lived. Combinations of partial

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resistances, which tend to have durability, are now considered to be safer options. Understanding and working with such resistance, however, requires a deeper knowledge of the genetic basis of the resistance. Breeders are now mapping the major genes involved and identifying varieties with known combinations. This extends the breeders an opportunity to define the risk associated with any known combination in varieties under test. In addition, the use of molecular markers to tease apart the contributions of partial resistances now provides an extremely useful tool for overcoming the threat of this disease. Longer term robust resistance based upon the 'stacking' of different sources with a proven level of durability must be the best solution. The effects of moderate resistances can be additive and combined to provide near immunity (Angus & Fenwick, 2008).

The wheat-growing areas of the world can be divided into epidemical zones within which relatively free movement of the rust spores occur (Saari & Prescott, 1985). The virulence of a rust pathogen tends to be similar throughout a zone, however, can vary from area to area within a zone provided the predominant cultivars in different areas carry different genes for resistance. It is worth mentioning that chemical control of rust diseases is un-economical and unhygienic too. So cultivation of resistant varieties is of immense significance, however, the presence of several races of each and the ever-changing nature of the pathogen complicate breeding for rust resistance. Stability in production is vital for sound wheat production system. Accordingly, identifying new genes from fresh sources and their incorporation into our wheat cultivars would obviously be beneficial for our stakeholders. The capacity to develop durable and efficient control methods against crop diseases is largely based on the knowledge of the pathogen population, its potential for the adaptation to new cultivars (Grant & Archer, 1983) and host genetic. Javed *et al.,* (2004) reported that field data from the yellow rust trap nurseries showed the presence of virulence for the genes *Yr*1, *Yr2*, *Yr*6, *Yr7* and *Yr9* in Pakistan during 1998-99.

The options other than varietal deployment are to identify and incorporate new genetic diversity in wheat, produce stable resistant genetic stocks and eventually transfer these new genes into some leading, presently resistant or even susceptible varieties. Development and adoption of high yielding wheat varieties with narrow genetic base, also influenced by farmer/consumer preference, has led to cultivating fewer varieties over a large area thereby creating genetic vulnerability to stress. This had been observed previously when the lead cultivars Pak-81 and Pirsabak-85 were seriously affected upon the emergence of virulence for the stripe rust genes *Yr9* and *Yr7*, respectively (Anon., 2004). Out of 8.303 million hectares, more than 5.8 million hectares (70%) of wheat production area is under the threat of stripe rust (Singh *et al.,* 2004). The wide distribution of pathogen virulence, therefore, requires identification of new resistance genes from fresh sources and their incorporation into our wheat cultivars. This would obviously be beneficial for our stake holders as at a very conservative estimate, the average annual losses due to rusts in Pakistan @ 2% is estimated at Rs.1,500 million at the present price levels.

Keeping in view of the above scenario for stripe rust, the research study was executed with the salient objective focusing on screening of high yielding rust tolerant wheat genotypes through:

i. Identification of broad based new sources of tolerance to the prevalent and new virulence of wheat rusts that are developing in nature to provide resistant / tolerant parent stocks.
ii. Evaluation of breeders' material for its disease reaction in adult stage and disease development conditions for early elimination of susceptible lines.
iii. Monitoring change in the rust reaction potential in the commercial varieties for early caution / warning and to provide information on which commercial varieties can be recommended for specific zones or could be withdrawn from general cultivation.

Materials and Methods

Trial site, seed sources and planting geometry: The trials pertaining to the screening of wheat germplasm for their resistance against stripe rust were conducted at the experimental area of Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi during 2005-07. During these investigations, 188 indigenous and international varieties/ cultivars/lines collected from NARC, BARI, AARI, CCRI and ICARDA were sown to observe the stripe rust response in field. Each entry was planted in a 5 meter row length, 30 cm apart. Two rows of Local White and Morocco, which are universal susceptible to wheat rusts, were planted around the nursery. In addition, a row of Morocco was also planted within the screening material after every 20^{th} entry to enhance inoculum pressure. The material was screened in natural conditions and no artificial inoculation was carried out. Three replications were made for each of the variety/line. A seedling rate of 100 kg ha^{-1} was used in each planting. The trials were managed with optimum nutrient application (150 N: 20 P: 0 K) while weeds were controlled manually.

Assessment of disease reaction: Observation on response and severity of stripe rust was recorded according to Leogering (1959). The severity was recorded as % of rust infection on the plants according to the modified Cobb's Scale (Peterson *et al.,* 1948). As severity determined by observation cannot be absolutely accurate, therefore, below 5% severity, the intervals used were trace (T) to 2. Usually 5% intervals were used from 5-20% severity and 10% intervals for higher readings. The response of a variety refers to the type of infection and was recorded in accordance with Table 1 and the disease reaction showed by the varieties / lines is given in Table 2.

Calculation for ACI and RRI: Coefficient of Infection (CI) was derived by multiplying response value with the intensity of infection in percent. Whereas, Average Coefficient of Infection (ACI) was calculated from the sum of CI values of each entry divided by the corresponding data recording years (Stubbs *et al.,* 1986). In this experiment we divided sums of CI by two as the data pertains to the years 2005-06 and 2006-07. The Relative Resistance Index (RRI) was calculated on a 0 to 9 scale, where 0 represents the most susceptible and 9 shows highly resistant variety (Table 3). The standard for desirable index was maintained ≤7 whereas value for acceptable index was fixed as 5. The following formula was used for calculation of RRI (Akhtar *et al.,* 2002).

$$RRI = \frac{(100\text{-CARPA})}{100} \times 9$$

Table 1. Field response of host plant against stripe rust.

Reaction	Description	Observation	Response value
No Disease	No visible infection	0	0.0
Resistant	Visible chlorosis or necrosis, no uredia are present	R	0.2
Res. – Mod. Resistant		RMR	0.3
Moderately Resistant	Small uredia surrounded by chlorotic/necrotic areas	MR	0.4
Mod. Res. – Mod. Sus		MR-MS	0.6
Moderately susceptible	Uredia medium size with no necrotic margins but possibly some distinct chlorosis	MS	0.8
Mod. Sus.-Susceptible		MS-S	0.9
Susceptible	Large uredia with no necrosis & little or no chlorosis	S	1.0

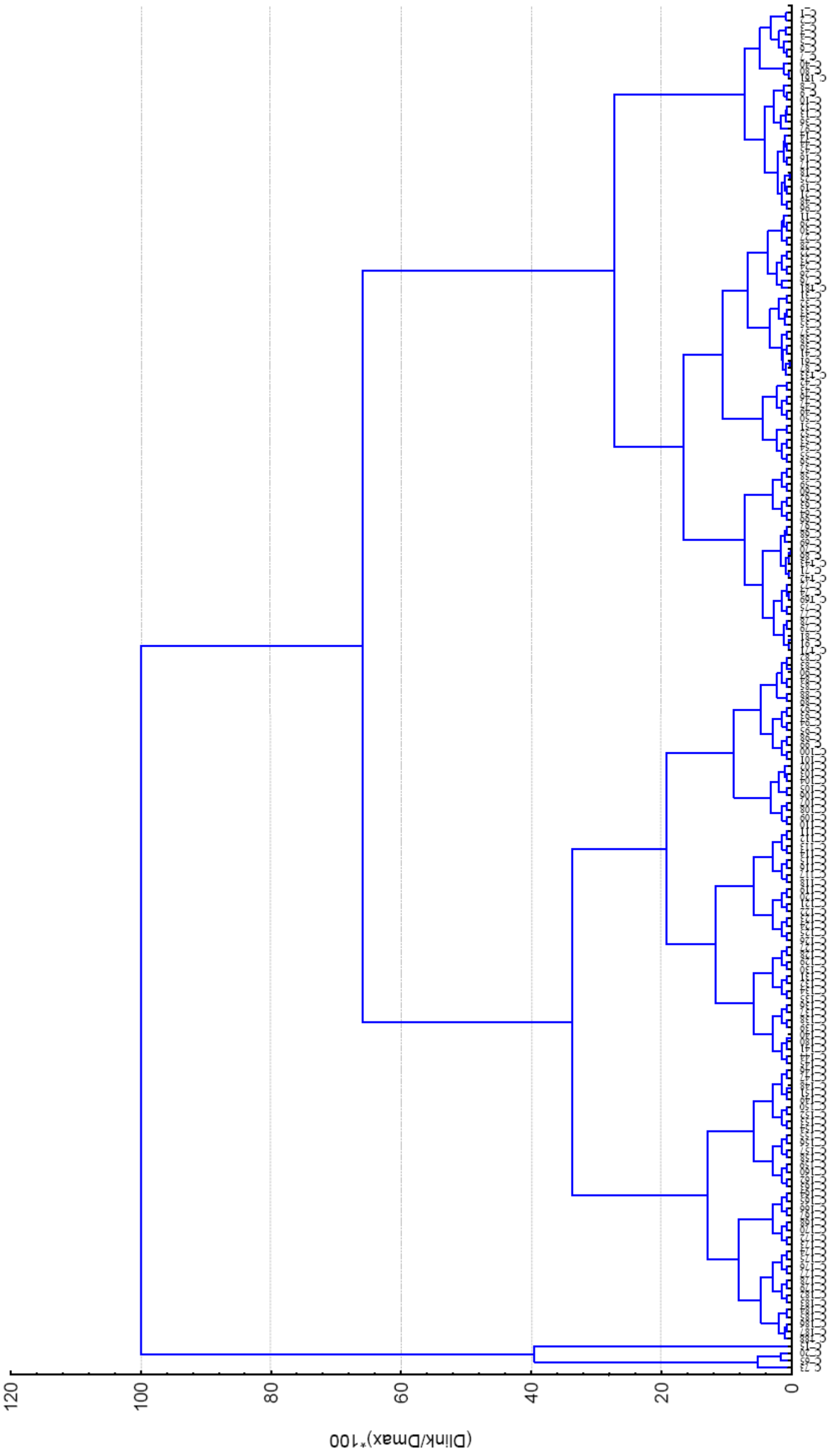
(Dlink/Dmax)*100
120
100
80
60
40
20
0

Table 2. Sources of wheat germplasm screened for strip rust resistance during the year 2005-06 and 2006-07.

Nos.	Line / Variety	Disease reaction		Source
		2005-06	2006-07	
65	RAWAL 87 (BARI, CHAKWAL), IQBAL 2000 (AARI, FAISALABAD), V 02172 (MICROLINE, FAISALABAD), 99FJ03 (MICROLINE, FATEHJANG), 1C020 (MICROLINE, BARI, CHAKWAL), 3C060 (B-LINE, BARI, CHAKWAL), 3C062 (B-LINE, BARI, CHAKWAL), 3C063 (B-LINE, BARI, CHAKWAL), 3C066 (B-LINE, BARI, CHAKWAL), Asfoor-3, Dajaj-5, Husi-2, Atris-1, Girwill-1, NR-189, DHARWAR DRY, KLEIN CHAMACO, PBW343, KLEIN CACIQUE, KAUZ/PASTOR, WEAVER /4/NAC/ TH.AC/3*PVN/3/MIRLO/BUC, CROC_1/AE.SQUARROSA (205)//KAUZ/3/SASIA, DHARWAR DRY/NESSER, SUJATA/SERI, PASTOR// SITE/MO/3/CHEN/AEGILOPS SQUARROSA (T…, FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/…, CHIL/2*STAR/5/ CANDO/R143// ENTE/MEXI_2/3/…, MUNIA//CHEN/ALTAR 84/3/CHEN/…, VIV90/ 91.28/5/ CNDO/R143/ ENTE/ MEXI_2/3/…, PJN/BOW// OPATA/3/ CROC_1/ AE.SQUARROSA (224)//…, VEE/MJI//2*TUI/3/PFAU/BOW//VEE#9, CHEN/AEGILOPS SQUARROSA (TAUS)/BCN/3/BAV92, CNDO/R143/ENTE/MEXI_2/3/…, RABE/6/ WRM/4/FN/3*TH//K58/2*N/3/AUS-6869/5/…, VEE/MJI//2*TUI/3/PASTOR, PASTOR/ BAV92, IRENA/BABAX//PASTOR, ND/VG9144// KAL/BB/3/ YACO/4/ CHIL/5/ PASTOR, CNO79//PF70354/MUS/3/ URES/JUN/KAUZ, URES// BUC/PVN/3/KAUZ/4/ FILIN, ND/VG9144//KAL/BB/3/YACO/4/CHIL/5/PASTOR, CROC_1/AE.SQUARROSA (224)//OPATA/3/PASTOR, BJY/COC//PRL/BOW/3/ATTILA, PARUS/PASTOR, FILIN/3/ CROC_1/ AE.SQUARROSA(205)// KAUZ/4/…, GEN*2// BUC/FLK/3/2 *PASTOR, VIV90/91.28// 2*PASTOR, FILIN/ 2*PASTOR, VEE/ MJI//2*TUI/ 3/2*PASTOR, MILAN/KAUZ//BABAX/3/BABAX, PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS…, TUI/CLMS, NAI60/HEINE VII//BUC/3/PSN/BOW//TUI, ATTILA*2/HUITES, SNI/2*PASTOR, TRAP#1.R1/2*PASTOR, SERI.1B*2/4/COOK/VEE//DOVE/SERI/3/GEN, SERI.1B*2//TAM200/TUI, BAVIACORA M 92, ATTILA, ATTILA*2//CHIL/BUC, WEAVER/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/…, SKAUZ/KS94U276//SKAUZ, BABAX/ KS91WGRC11//BABAX, BABAX/KS94U276//BABAX	0	0	NARC, BARI, AARI, CCRI, ICARDA
1	WEEBILL1	5 R	5 R	ICARDA
12	UQAB 2000 (AARI, FAISALABAD), SALEEM 2000 (CCRI, PIRSABAQ), KHYBER 87 (CCRI, PIRSABAQ), NR-199, PJN/BOW//OPATA/3/ CROC_1/ AE.SQUARROSA (224)//…, TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/5/KUAZ/6/…, SERI M 82, SERI.1B*2/3/KAUZ*2/BOW//KAUZ, WEAVER/STAR//BORL95, SKAUZ/KS93U76 //SKAUZ, SKAUZ/KS94U215//SKAUZ, SKAUZ/KS91WGRC11// SKAUZ	TR	TR	NARC, BARI, AARI, CCRI, ICARDA
1	SIREN/CLMS//SIREN	TR R	TR R	ICARDA
1	3C065 (B-LINE, BARI, CHAKWAL)	1 MR	5 MR	NARC, BARI, AARI, CCRI

Table 2. (Cont'd.).

Nos.	Line / Variety	Disease reaction		Source
		2005-06	2006-07	
1	3C061 (B-LINE, BARI, CHAKWAL)	1 MR MS	1 MR MS	NARC, BARI, AARI, CCRI
4	GA 2002 (BARI, CHAKWAL), PBW65/2*SERI.1B, PFAU/SERI.1B//AMAD, SERI.1B// KAUZ/HEVO/3/AMAD	1 MR MS	5 MR MS	NARC, BARI, AARI, CCRI
1	PASTOR	1 MR MS	10 MR MS	ICARDA
1	CHAKWAL 86 (BARI, CHAKWAL)	40 MR MS	50 MR MS	NARC, BARI, AARI, CCRI
4	CHAKWAL 97, ARIV92/BABAX//PASTOR, PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS…, ATTILA*2/PVN	10 MR MS	10 MR MS	ICARDA
5	CHAKWAL 86, KAUZ//PRL/VEE#6/3/BAV92, HUW234+LR34/3/KAUZ*2/ TRAP// KAUZ, KAMBARA2, ATTILA*2/STAR, BABAX/LR42/BABAX	5 MR MS	10 MR MS	ICARDA
2	CNDO/R143/ENTE/MEXI_2/3/…, CHEN/AEGILOPS SQUARROSA (TAUS)// BCN/3/BAV92	10 MR MS	15 MR MS	ICARDA
2	URES/PRL//BAV92, PASTOR//HXL7573/2*BAU	10 MR MS	20 MR MS	ICARDA
3	ATTILA*2//CHIL/BUC, WEEBILL4, HUW234+LR34/PRINIA	10 MR MS	10 MR MS	ICARDA
1	PBW65/2*PASTOR	5 MR MS	5 MR MS	ICARDA
2	DHARWAR DRY//HXL7573/2*BAU, FRET2	20 MR MS	20 MR MS	ICARDA
1	PASTOR/3/MUNIA//CHEN/ALTAR 84/5/CNDO/R143//…	20 MR MS	30 MR MS	ICARDA
1	BABAX/LR43/BABAX	20 MR MS	40 MR MS	ICARDA
6	3C069 (B-LINE, BARI, CHAKWAL), 00FJ03 (MICROLINE, FATEHJANG), 106/20, PRL/2*PASTOR, ATTILA*2/CROW, HIDHAB	10 MS S	10 MS S	NARC, BARI, AARI, CCRI, ICARDA
6	SULEMAN 96 (CCRI, PIRSABAQ), 116/10, BAVIACORA M 92, ATTILA*2/4/ CAR//KAL/BB/3/NAC, KAMBARA1, HUW234+LR34*2/AMAD	5 MS S	10 MS S	NARC, BARI, AARI, CCRI
2	PAVON/SERI, 2495 (MICROLINE BAHAWALPUR)	20 MS S	20 MS S	ICARDA, NARC, BARI, AARI, CCRI
3	PAVON/SERI, MIRONOVSKA #2//CHIL/CHUM18, 124/2	30 MS S	40 MS S	ICARDA
1	125/1	40 MS S	50 MS S	ICARDA
1	ATTILA*2/STAR	20 MS S	50 MS S	ICARDA
1	WEAVER/OCI//BORL95	10 MS S	30 MS S	ICARDA
1	BABAX/LR42/BABAX	30 MS S	50 MS S	ICARDA
2	ATTILA*2/PASTOR, DHARWAR DRY / SITTA	10 MS S	20 MS S	ICARDA
1	CHAM 6	15 MS S	20 MS S	ICARDA
1	DHARWAR DRY / NESSER	20 MS S	30 MS S	ICARDA
1	98C017 (NATIONAL LINE)	10 MS	10 MS	NARC, BARI, AARI, CCRI

Results and Discussion

The results revealed that intensity of disease infection during the year 2006-07 was higher as compared to the wheat year of 2005-06. This severity may be attributed to the relative dry weather, which prevailed during the year 2005-06. More rainfalls during 2006-07 favored the intensity of disease in almost all varieties. The results are in line with the work done by Te-Best *et al*., (2008) who reported that intensity of stripe rust is favored by a model with temperature, humidity and rainfall. It is evident from Table 3 that out of 188 varieties/lines, 77 responded with zero average coefficient of infection and highest RRI valuing 9, 70 exhibited RRI values ranging 7.2 to 8.94, 26 cultivars showed RRI in the range of 5.85 to 6.97 whereas remaining represented values of RRI below 5. It was, therefore, concluded that most of the lines had a great potential to be used as a resistant germplasm source against stripe rust. The results have shown that reliance upon Inquilab-91 should have to be minimized as the variety has shown greater susceptibility than the previous years. The results are in line with those of Singh *et al*., (2004) who reported that *Yr27* gene present in a widely cultivated varieties Inquilab-91 in Pakistan and PBW-343 in India has broken down resulting in severe economic losses (Kisana, 2003). The data was later on analyzed for cluster analysis. It is evident from the dendrogram (Fig. 1) that the entire varieties could be divided into two clusters at 70 % linkage distance, wherein one cluster comprised only 4 cultivars whereas the remaining 84 varieties fell in another cluster. We, however, observed split in this big cluster at 60 % linkage distance wherein 4, 95 and 89 lines in cluster I, II and III, respectively was observed. A major break through was observed at 20% linkage distance wherein the group of 4 was segregated and 6 clusters vis-à-vis cluster I, II, III, IV, V and VI each comprising 3, 1, 57, 38, 61 and 28 lines, respectively. It was observed that the cultivars generally grouped in clusters according to their potential of resistance against the disease. The most susceptible were grouped under cluster III (60% linkage distance). But under this cluster these showed further split. It was amazing to note that the lines 124/2 and 101/25 falling under acceptable range grouped with lines 106/20 and 116/10 at higher RRI value. Likewise, majority of the lines with highest RRI value of 9 fell under cluster II except the lines PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA, TOB/ERA/TOB/CNO67/3/PLO/4/VEE#5/5/KUAZ/6/, DHARWAR DRY/ NESSER, CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/BAV92, CNDO/R143/ENTE/MEXI_2/3/ and ATTILA*2//CHIL/BUC were represented under cluster III at 60% linkage distance. Such uneven distribution of cultivars having lower RRI values and their grouping with those having highest RRI values may be attributed to their performance under moisture stress conditions of the arid zone. Our results are in conformity with those of Ali *et al*., (2008) who observed that most of the lines exhibit more resistance under high disease pressure as compared to the susceptible check. Such lines may be exploited to explore and used for their resistance gene to minimize damages caused by strip rust. We may, therefore, conclude that out of 188 cultivars/lines, 150 had RRI value $\geq 7 \leq 9$ and were in desirable range. Whereas, 28 cultivars were included among the acceptable range having RRI value $\geq 5 \leq 7$. Only 10 cultivars showed RRI value <5 and placed under undesirable range. It is envisaged that there is still a great potential to exploit the existing sources of wheat germplasm to develop stripe rust resistant varieties. For this purpose, process may be continued with more lines and at more locations for determination of resistance against yellow rust as well as for stability of the germplasm over years alongwith other desirable characteristics before final approval of the variety.

Table 2. (Cont'd.).

Nos.	Line / Variety	Disease reaction		Source
		2005-06	2006-07	
4	TOB/ERA//TOB/ CNO67/3/PLO/4/ VEE#5/5/ KAUZ/6/…, PJN/BOW// OPATA/3/ PASTOR, 2KC033 (NATIONAL LINE), 99FJ016 (MICROLINE, FATEHJANG)	10 MS	20 MS	ICARDA, NARC, BARI, AARI, CCRI
6	3C068 (B-LINE, BARI, CHAKWAL), TOB/ERA//TOB/CNO67/3/PLO/4/ VEE#5/5/ KUAZ/6/…, SRMA/ TUI//BUBAX, ATTILA*2/ STAR, ATTILA/ 2*PASTOR, TRAP#1.R1/2*SERI.1B	30 MS	40 MS	NARC, BARI, AARI, CCRI, ICARDA
7	CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/4/NAC/…, CNDO/R143/ ENTE/ MEXI_2/3/…, FN/2*PASTOR, URES/PRL//BAV92, BABAX/PASTOR//AMAD, HUW234+LR34/ PRINIA, ATTILA*2//CHIL/BUC	5 MS	10 MS	ICARDA
4	URES/PRL//BAV92, KALYANSONA, PRL/2*SERI.1B, PASTOR/3/ALTAR 84/ AEGILOPS SQUARROSA (TAUS…	20 MS	30 MS	ICARDA
1	HUW234+LR34	-	5 MS	ICARDA
3	ATTILA*2/PBW65, ATTILA*2/STAR, HUW234+LR34*2//PRL/VEE#10	20 MS	20 MS	ICARDA
2	HUW234+LR34*2/3/KAUZ*2/TRAP//KAUZ, ATTILA*2/3/KAUZ*2/TRAP//KAUZ	5 MS	5 MS	ICARDA
1	ATTILA*2/AMAD	1 MS	1 MS	ICARDA
1	WEAVER/OCI//BORL95	40 MS	40 MS	ICARDA
1	BABAX/LR42/BABAX	20 MS	40 MS	ICARDA
1	INQALAB 91 (AARI, FAISALABAD)	20 MS S	40 S	NARC, BARI, AARI, CCRI
1	CHAKWAL 97 (BARI, CHAKWAL)	10 S	10 S	NARC, BARI, AARI, CCRI
1	AS 2002 (AARI, FAISALABAD)	20 S	20 S	NARC, BARI, AARI, CCRI
5	MAN 1 (NATIONAL LINE), V 02169 (MICROLINE, FAISALABAD), 1C001 (MICROLINE, BARI, CHAKWAL), 1C002 (MICROLINE, BARI, CHAKWAL), NR 234 (MICROLINE, NARC, ISLAMABAD)	20 S	30 S	NARC, BARI, AARI, CCRI
3	1C007 (MICROLINE, BARI, CHAKWAL), 101/25, SH 2002 (AARI, FAISALABAD)	30 S	30 S	NARC, BARI, AARI, CCRI, ICARDA
1	HAIDER 2000 (CCRI, PIRSABAQ)	50 S	40 S	NARC, BARI, AARI, CCRI
1	00BT004 (MICROLINE, BIO.TECH.FSD)	50 S	50 S	NARC, BARI, AARI, CCRI
3	MARGALA 99 (BARI, CHAKWAL), URES/JUN//KAUZ/3/BABAX, LOCAL CHECK	50 S	70 S	NARC, BARI, AARI, CCRI
2	V 02166 (MICROLINE, FAISALABAD), PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS…	60 S	80 S	NARC, BARI, AARI, CCRI, ICARDA
1	3C067 (B-LINE, BARI, CHAKWAL)	90 S	100 S	NARC, BARI, AARI, CCRI
1	00C010 (NATIONAL LINE)	100 S	100 S	NARC, BARI, AARI, CCRI
1	Katila II	10 S	10 S	ICARDA
1	BABAX/LR39/BABAX	40 S	50 S	ICARDA
1	KAMBARA1	20 S	40 S	ICARDA

Table 3. Screening results of wheat germplasm based on Coefficient of Infection, Relative Resistance Index recorded during the year 2005-06 and 2006-07.

Line / Variety	Disease reaction		Coefficient of infection		CI Total	ACI	RRI
	2005-06	2006-07	2005-06	2006-07			
RAWAL 87, IQBAL 2000, V 02172, 99FJ03, 1C020, 3C060, 3C062, 3C063, Asfoor–3, Dajaj–5, Husi–2, Atris–1, Girwill–1, NR–189, DHARWAR DRY, KLEIN CHAMACO, PBW343, KLEIN CACIQUE, KAUZ/PASTOR, WEAVER/4/NAC/TH.AC/3*PVN/3/MIRLO/BUC, CROC_1/ AE.SQUARROSA (205)//KAUZ/3/SASIA, DHARWAR DRY / NESSER, SUJATA / SERI, PASTOR// SITE/MO/ 3/CHEN/AEGILOPS SQUARROSA (T…, FILIN/IRENA/5/CNDO/R143// ENTE/MEXI_2/3/…, CHIL/2*STAR/5/CANDO/R143//ENTE/MEXI_2/3/…, MUNIA//CHEN/ ALTAR, 84/3/ CHEN/, VIV90/91.28/ 5/ CNDO/ R143/ ENTE/MEXI_2/ 3/…, PJN/BOW// OPATA/ 3/CROC_1/ AE.SQUARROSA (224)//…, VEE/MJI// 2*TUI/3/ PFAU/BOW//VEE #9, CHEN/ AEGILOPS SQUARROSA (TAUS)/BCN/3/BAV92, CNDO/R143/ENTE/MEXI_2/3/…, RABE/6/WRM/4/ FN/ 3*TH//K58/2*N/3/AUS-6869/5/…, VEE/MJI//2*TUI/3/PASTOR, PASTOR/ BAV92, IRENA/ BABAX// PASTOR, ND/VG9144// KAL/BB/3/ YACO/4/ CHIL/ 5/PASTOR, CNO79// PF70354/MUS/3/URES/JUN/KAUZ, URES//BUC/PVN/3/KAUZ/4/FILIN, ND/ VG9144// KAL/ BB/ 3/YACO/4/CHIL/5/PASTOR, CROC_1/ AE.SQUARROSA(224)// OPATA/3/ PASTOR, BJY/COC// PRL/ BOW/3/ ATTILA, PARUS/ PASTOR, FILIN/3/ CROC_1/ AE.SQUARROSA(205)// KAUZ/4/…, GEN*2//BUC/FLK/3/2*PASTOR, VIV90/91.28// 2*PASTOR, FILIN/2*PASTOR, VEE/MJI//2*TUI/3/2*PASTOR, MILAN/KAUZ//BABAX/ 3/BABAX, PASTOR/3/ALTAR 84/ AEGILOPS SQUARROSA (TAUS…, TUI/CLMS, NAI60/HEINE VII// BUC/3/PSN/BOW//TUI, ATTILA*2/HUITES, SNI/2*PASTOR, TRAP#1.R1/2*PASTOR, SERI.1B*2/4/COOK/ VEE// DOVE/SERI/3/GEN, SERI.1B*2//TAM200/ TUI, BAVIACORA M 92, ATTILA, ATTILA*2// CHIL/BUC, WEAVER/9/KT/BAGE// FN/U/3/BZA/4/TRM/5/…, SKAUZ/ KS94U276//SKAUZ, BABAX/KS91WGRC11//BABAX, BABAX/KS94U276//BABAX	0	0	0	0	0	0	9
WEEBILL1	5 R	5 R	1	1	2	1	8.91
UQAB 2000 (AARI, FAISALABAD), SALEEM 2000 (CCRI, PIRSABAQ), KHYBER 87 (CCRI, PIRSABAQ), NR–199, PJN/BOW//OPATA/3/CROC_1/AE.SQUARROSA(224)//…, TOB/ERA// TOB/CNO67/3/PLO/4/VEE#5/5/KUAZ/6/…, SERI M 82, SERI.1B*2/3/KAUZ*2/BOW//KAUZ, WEAVER/STAR//BORL95, SKAUZ/KS93U76//SKAUZ, SKAUZ/KS94U215//SKAUZ	TR	TR	0	0	0	0	9
SKAUZ/KS91WGRC11//SKAUZ	0	TR	0	0	0	0	9
SIREN/CLMS//SIREN	TR R	TR R	0	0	0	0	9
3C065 (B-LINE, BARI, CHAKWAL)	1 MR	5 MR	0.4	2	2.4	1.2	8.892
3C061 (B-LINE, BARI, CHAKWAL)	1 MR MS	1 MR MS	0.6	0.6	1.2	0.6	8.946
GA 2002 (BARI, CHAKWAL)	1 MR MS	5 MR MS	0.6	3	3.6	1.8	8.838
CHAKWAL 86 (BARI, CHAKWAL)	40 MR MS	50 MR MS	24	30	54	27	6.57
Chakwal 97	10 MR MS	10 MR MS	6	6	12	6	8.46
PASTOR/3/MUNIA//CHEN/ALTAR 84/5/CNDO/R143//…	20 MR MS	30 MR MS	12	18	30	15	7.65
CHAKWAL 86	5 MR MS	10 MR MS	3	6	9	4.5	8.595
CNDO/R143/ENTE/MEXI_2/3/…	10 MR MS	15 MR MS	6	9	15	7.5	8.325

Table 3. (Cont'd.).

Line / Variety	Disease reaction		Coefficient of infection		CI Total	ACI	RRI
	2005-06	2006-07	2005-06	2006-07			
CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/BAV92	10 MR MS	15 MR MS	6	9	15	7.5	8.325
KAUZ//PRL/VEE#6/3/BAV92	5 MR MS	10 MR MS	3	6	9	4.5	8.595
URES/PRL//BAV92	10 MR MS	20 MR MS	6	12	18	9	8.19
ARIV92/BABAX//PASTOR	10 MR MS	10 MR MS	6	6	12	6	8.46
PASTOR//HXL7573/2*BAU	10 MR MS	20 MR MS	6	12	18	9	8.19
PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS…	10 MR MS	10 MR MS	6	6	12	6	8.46
DHARWAR DRY//HXL7573/2*BAU	20 MR MS	20 MR MS	12	12	24	12	7.92
ATTILA*2//CHIL/BUC	10 MR MS	10 MR MS	6	6	12	6	8.46
WEEBILL4	10 MR MS	10 MR MS	6	6	12	6	8.46
KAMBARA2	5 MR MS	10 MR MS	3	6	9	4.5	8.595
PBW65/2*SERI.1B	1 MR MS	5 MR MS	0.6	3	3.6	1.8	8.838
PFAU/SERI.1B//AMAD	1 MR MS	5 MR MS	0.6	3	3.6	1.8	8.838
SERI.1B//KAUZ/HEVO/3/AMAD	1 MR MS	5 MR MS	0.6	3	3.6	1.8	8.838
PASTOR	1 MR MS	10 MR MS	0.6	6	6.6	3.3	8.703
PBW65/2*PASTOR	5 MR MS	5 MR MS	3	3	6	3	8.73
HUW234+LR34/PRINIA	10 MR MS	10 MR MS	6	6	12	6	8.46
HUW234+LR34/3/KAUZ*2/TRAP//KAUZ	5 MR MS	10 MR MS	3	6	9	4.5	8.595
FRET2	20 MR MS	20 MR MS	12	12	24	12	7.92
ATTILA*2/PVN	10 MR MS	10 MR MS	6	6	12	6	8.46
ATTILA*2/STAR	5 MR MS	10 MR MS	3	6	9	4.5	8.595
BABAX/LR42/BABAX	5 MR MS	10 MR MS	3	6	9	4.5	8.595
BABAX/LR43/BABAX	20 MR MS	40 MR MS	12	24	36	18	7.38
3C069 (B-LINE, BARI, CHAKWAL)	10 MS S	10 MS S	9	9	18	9	8.19
SULEMAN 96 (CCRI, PIRSABAQ)	5 MS S	10 MS S	4.5	9	13.5	6.75	8.3925
00FJ03 (MICROLINE, FATEHJANG)	10 MS S	10 MS S	9	9	18	9	8.19
2495 (MICROLINE BAHAWALPUR)	20 MS S	30 MS S	18	27	45	22.5	6.975
116/10	5 MS S	10 MS S	4.5	9	13.5	6.75	8.3925
106/20	10 MS S	10 MS S	9	9	18	9	8.19
124/2	30 MS S	40 MS S	27	36	63	31.5	6.165
125/1	40 MS S	50 MS S	36	45	81	40.5	5.355
PRL/2*PASTOR	10 MS S	10 MS S	9	9	18	9	8.19
ATTILA*2/CROW	10 MS S	10 MS S	9	9	18	9	8.19
PAVON/SERI	20 MS S	20 MS S	18	18	36	18	7.38
BAVIACORA M 92	5 MS S	10 MS S	4.5	9	13.5	6.75	8.3925
HIDHAB	10 MS S	10 MS S	9	9	18	9	8.19

Table 3. (Cont'd.).

Line / Variety	Disease reaction		Coefficient of infection		CI Total	ACI	RRI
	2005-06	2006-07	2005-06	2006-07			
DHARWAR DRY / SITTA	10 MS S	20 MS S	9	18	27	13.5	7.785
CHAM 6	15 MS S	20 MS S	13.5	18	31.5	15.75	7.5825
PAVON/SERI	30 MS S	40 MS S	27	36	63	31.5	6.165
DHARWAR DRY / NESSER	20 MS S	30 MS S	18	27	45	22.5	6.975
MIRONOVSKA #2//CHIL/CHUM18	30 MS S	40 MS S	27	36	63	31.5	6.165
ATTILA*2/4/CAR//KAL/BB/3/NAC	5 MS S	10 MS S	4.5	9	13.5	6.75	8.3925
KAMBARA1	5 MS S	10 MS S	4.5	9	13.5	6.75	8.3925
ATTILA*2/PASTOR	10 MS S	20 MS S	9	18	27	13.5	7.785
HUW234+LR34*2/AMAD	5 MS S	10 MS S	4.5	9	13.5	6.75	8.3925
ATTILA*2/STAR	20 MS S	50 MS S	18	45	63	31.5	6.165
WEAVER/OCI//BORL95	10 MS S	30 MS S	9	27	36	18	7.38
BABAX/LR42/BABAX	30 MS S	50 MS S	27	45	72	36	5.76
98C017 (NATIONAL LINE)	10 MS	10 MS	8	8	16	8	8.28
2KC033 (NATIONAL LINE)	10 MS	20 MS	8	16	24	12	7.92
99FJ016 (MICROLINE, FATEHJANG)	10 MS	20 MS	8	16	24	12	7.92
3C068 (B-LINE, BARI, CHAKWAL)	30 MS	40 MS	24	32	56	28	6.48
TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/5/KUAZ/6/…	30 MS	40 MS	24	32	56	28	6.48
CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/4/NAC/…	5 MS	10 MS	4	8	12	6	8.46
PJN/BOW//OPATA/3/PASTOR	10 MS	20 MS	8	16	24	12	7.92
CNDO/R143/ENTE/MEXI_2/3/…	5 MS	10 MS	4	8	12	6	8.46
URES/PRL//BAV92	20 MS	30 MS	16	24	40	20	7.2
URES/PRL//BAV92	5 MS	10 MS	4	8	12	6	8.46
TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/5/KAUZ/6/…	10 MS	20 MS	8	16	24	12	7.92
PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS…	20 MS	30 MS	16	24	40	20	7.2
SRMA/TUI//BUBAX	30 MS	40 MS	32	24	56	28	6.48
FN/2*PASTOR	5 MS	10 MS	4	8	12	6	8.46
ATTILA*2/STAR	30 MS	40 MS	24	32	56	28	6.48
BABAX/PASTOR//AMAD	5 MS	10 MS	4	8	12	6	8.46
ATTILA/2*PASTOR	30 MS	40 MS	24	32	56	28	6.48
KALYANSONA	20 MS	30 MS	16	24	40	20	7.2
HUW234+LR34	O	5 MS	0	4	4	2	8.82
TRAP#1.R1/2*SERI.1B	30 MS	40 MS	24	32	56	28	6.48
PRL/2*SERI.1B	20 MS	40 MS	16	32	48	24	6.84
HUW234+LR34*2//PRL/VEE#10	20 MS	20 MS	16	16	32	16	7.56

Table 3. (Cont'd.).

Line / Variety	Disease reaction		Coefficient of infection		CI Total	ACI	RRI
	2005-06	2006-07	2005-06	2006-07			
HUW234+LR34/PRINIA	5 MS	10 MS	4	8	12	6	8.46
HUW234+LR34*2/3/KAUZ*2/TRAP//KAUZ	5 MS	5 MS	4	4	8	4	8.64
ATTILA*2//CHIL/BUC	5 MS	10 MS	4	8	12	6	8.46
ATTILA*2/3/KAUZ*2/TRAP//KAUZ	5 MS	5 MS	4	4	8	4	8.64
ATTILA*2/AMAD	1 MS	1 MS	0.8	0.8	1.6	0.8	8.928
ATTILA*2/PBW65	20 MS	20 MS	16	16	32	16	7.56
ATTILA*2/STAR	20 MS	20 MS	16	16	32	16	7.56
WEAVER/OCI//BORL95	40 MS	40 MS	32	32	64	32	6.12
BABAX/LR42/BABAX	20 MS	40 MS	16	32	48	24	6.84
INQALAB 91 (AARI, FAISALABAD)	10 MS S	40 S	9	40	49	24.5	6.795
CHAKWAL 97 (BARI, CHAKWAL)	10 S	10 S	10	10	20	10	8.1
AS 2002 (AARI, FAISALABAD)	20 S	20 S	20	20	40	20	7.2
MAN 1 (NATIONAL LINE)	20 S	30 S	20	30	50	25	6.75
V 02169 (MICROLINE, FAISALABAD)	20 S	30 S	20	30	50	25	6.75
1C001 (MICROLINE, BARI, CHAKWAL)	20 S	30 S	20	30	50	25	6.75
1C002 (MICROLINE, BARI, CHAKWAL)	20 S	30 S	20	30	50	25	6.75
NR 234 (MICROLINE, NARC, ISLAMABAD)	20 S	30 S	20	30	50	25	6.75
1C007 (MICROLINE, BARI, CHAKWAL)	30 S	30 S	30	30	60	30	6.3
SH 2002 (AARI, FAISALABAD)	40 S	30 S	40	30	70	35	5.85
HAIDER 2000 (CCRI, PIRSABAQ)	50 S	40 S	50	40	90	45	4.95
00BT004 (MICROLINE, BIO.TECH.FSD)	50 S	50 S	50	50	100	50	4.5
MARGALA 99 (BARI, CHAKWAL)	50 S	60 S	50	60	110	55	4.05
V 02166 (MICROLINE, FAISALABAD)	70 S	80 S	70	80	150	75	2.25
3C067 (B-LINE, BARI, CHAKWAL)	90 S	100 S	90	100	190	95	0.45
00C010 (NATIONAL LINE)	100 S	100 S	100	100	200	100	0
Katila II	10 S	10 S	10	10	20	10	8.1
101/25	30 S	30 S	30	30	60	30	6.3
PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS…	60 S	80 S	60	80	140	70	2.7
URES/JUN//KAUZ/3/BABAX	50 S	70 S	50	70	120	60	3.6
LOCAL CHECK	50 S	60 S	50	60	110	55	4.05
BABAX/LR39/BABAX	40 S	50 S	40	50	90	45	4.95
KAMBARA1	20 S	40 S	20	40	60	30	6.3

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(Received for publication 14 March 2009)