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VULNERABILITY OF PAKISTANI WHEAT (*TRITICUM AESTIVUM* L.) VARIETIES AGAINST STRIPE RUST UNDER RAIN-FED CLIMATE OF THE NORTHERN PUNJAB AND NWFP

SYED NADEEM AFZAL[1], M. I. HAQUE[*1], ABDUL RAUF[1], IFTIKHAR AHMAD[2] AND SYEDA SADIQA FIRDOUS[3]

[1]*Department of Plant Pathology, PMAS-Arid Agriculture University, Rawalpindi, Pakistan*
[2]*National Agricultural Research Centre, Islamabad, Pakistan*
[3]*Department of Botany, PMAS-Arid Agriculture University, Rawalpindi, Pakistan.*

Abstract

Exploring resistance potential of commercial wheat varieties is imperative to combat against the escalating stripe rust dilemma in the wheat cultivated areas of the northern Punjab and NWFP. A two years field-based screening of 57 Pakistani commercial varieties to evaluate their potential against stripe rust was conducted during 2005-06 and 2006-07. The commercial varieties, Soorab-96 (barley), Tatara and GA-2002 were the only three that exhibited resistant response to stripe rust at all the WSRN sites during experimentation years. There were 5 cultivars viz., Pavon-76, Kohsar-93, Fakhr-e-Sarhad, Iqbal-2000 and Durum-97 that showed a combination of resistance and partial resistance responses at the six hot spots. Contrarily MH-97, Inquilab-91, Sindh-81, Zargoon, Faisalabad-83, Faisalabad-85, Kaghan-93, Kirin-95, Kohinoor-83, LU-26, Nowshera-96, Punjab-96, Sariab-92, Sarsabz, Tandojam-83, SH-2002, Pak-81, Bahawalpur-97, Rothas-90, Suleman-96, WL-711, Zardana, Abadgar-93, Watan-94, Moomal-2002 and Margalla-99 displayed susceptible reactions at all locations except Sialkot. The compiled field results exhibit that although the virulence frequency for some of the stripe rust resistance genes remained low, yet the presence of virulence against them is alarming under the circumstances when genetic base of resistance is stumpy in the presently cultivated varieties.

Introduction

Stripe rust caused by an obligate parasite *Puccinia striiformis* Westend. f. sp. *tritici* Eriks. (*Pst*), precincts wheat (*Triticum aestivum* L.) production throughout the world. This pathogen reportedly infects numerous wheat and barley cultivars as well as certain grass species (Stubbs, 1985). Stripe rust of wheat has been reported from more than 60 countries of the world and all the continents except Antarctica (Chen, 2005). Varieties often appear to lose their resistance due to cultivation in an area of its non-adaptability or change in virulence, which may either be due to appearance of a new race(s) or change in the composition of the existing races (Kilpatrick, 1975).

If a susceptible variety is under cultivation on large scale and weather turns favourable for the stripe rust pathogen, the yield losses can be unbearable (Aqil & Hussain, 2004). So far, four major stripe rust epidemics with intensity exceeding 20% have been reported during 1973 (35%), 1978 (55%), 1995 (37.5%) and 2003 (20%) while the stripe rust intensity has never gone below 8% in the country's history since 1950s (Ahmad, 2004). After the dawn of new millennium, the rust intensity is heading towards an epidemic situation with every passing year. During these epidemic years, the extensively cultivated resistant wheat cultivars Pirsabak-85, Pak-81 and Inquilab-91 possessing resistance genes *Yr7, Yr9* and *Yr27* were brutally attacked by the corresponding

[*]Corresponding author: Tel: +92-(51) 9290239 irfhaque@gmail.com
Phone: (+92 51) 9062243 Fax:(+92 51) 9290160

stripe rust virulent races that rendered the varieties susceptible (Khan & Mumtaz, 2004). Virulence for *Yr*9, which was widely deployed in bread wheat cultivars such as Seri82, Giza64 and Mexipak, spread rapidly throughout the Middle East region, Yemen and Ethiopia in the late 1980s (Wellings *et al.*, 2000). After the breakdown of *Yr*9 resistance gene in the final decade of the last century, several cultivars were released with the incorporation of resistance gene *Yr*27. One such important and very well known cultivar of the north-western Pakistan is Inquilab-91, which inspite of having potential to exhibit high yield in disease stress conditions (Afzal *et al.*, 2008) is highly vulnerable to stripe rust (Singh *et al.*, 2004). Wellings (2008) also confirmed *Pst* pathotype with virulence for the *Yr27* that arose as a single mutation derivative from the 'Jackie' pathotypes and is given the common name 'Jackie *Yr27*' pathotype. During 2004-05, stripe rust expressed its severity in the upper Punjab and NWFP thus posed a serious threat against sustainable wheat production. Due to prevalence of highly conducive environment for stripe rust development during April 2007 in Baluchistan, the stripe rust severity ranged from 5S-80S, 60S-80S, 5MS-80S, 5S-60S and traces to 80S in district Quetta, Mustung, Pishin, Loralai and Qilla Saifullah, respectively (Hussain Nasir, Personal communication).

Since, chemical control of rust is un-economical so cultivation of resistant varieties is of immense significance, however, presence of numerous races of each and the ever-transforming nature of the pathogens obscure breeding for rust resistance. During the years, many superior wheat cultivars have been developed with an exceptional degree of resistance to one or more rust diseases but the disease situation never remained static which thus emphasis that breeding of new strains of wheat resistant to rusts is an incessant process (Bariana *et al.*, 2007). Development and use of resistant cultivars possessing diverse and well characterized genes is integral for sustainable wheat production (Kaur *et al.*, 2008).

The stripe rust outbreaks in the past emphasizes to avoid monoculture of a single wheat variety on large scale besides signifies the importance of identifying stripe rust resistant wheat varieties and their cultivation according to different ecological zones of the country. Severe epidemics on wide scale could be avoided through use of durable resistance and diversification of resistance genes (Chen *et al.*, 2002). Monitoring of susceptible varieties to stripe rust is imperative so that new virulences with the potential to overcome resistance genes currently deployed in the wheat cultivars can be detected. An attempt has been made through the anticipated research to encompass information pertaining to the impact of stripe rust on commercially cultivated Pakistani wheat varieties through their response in terms of susceptibility under prevailing natural environmental conditions at hot spots in the Northern Punjab and NWFP.

Materials and Methods

To assess performance and response of commercial varieties against stripe rust in the Northern Punjab and NWFP, the wheat stripe rust nurseries (WSRNs) were established and frequently surveyed from 2nd week of February to the 1st week of April during 2006 and 2007. Data from all the nurseries was recorded thrice during the month of March, but was kept under regular observation from February till April of 2006 and 2007.

Establishment of WSRNs: The nurseries were established at six selected locations (Table 1) that serve as hot spots for development of stripe rust. Detail of WSRN, comprising of a universally susceptible wheat cultivar – Morocco as a check along with 57 commercial cultivars acquired from Crop Disease Research Program, NARC, Murree is given in Table 2.

Table 1. Location of the established wheat stripe rust nurseries.

Province	Location
Punjab	Pulses Research Station (PRS), Sahowali, Sialkot; PMAS – Arid Agriculture University (PMAS-AAUR), Rawalpindi; and National Agricultural Research Centre (NARC), Islamabad.
NWFP	Cereal Crop Research Institute (CCRI), Pirsabak, Nowshera; NWFP Agricultural University (AUP), Peshawar; and Nuclear Institute for Food and Agriculture (NIFA), Tarnab, Peshawar.

Stripe rust monitoring: Each entry of the nursery was planted in a single meter row length, 30 cm apart. Two rows of universally susceptible spreaders consisting of Local White and Morocco were planted around the nursery. In addition, a row of susceptible check (Morocco) was also raised at every 20th entry. At the entire field WSRNs locations, stripe rust severity was taken as percent of rust infection on wheat plants according to the modified Cobb's scale (Peterson *et al.*, 1948) and the field response scale referred to the infection type as described in Table 3 (Roelf *et al.*, 1992; Mcintosh *et al.*, 1995). The observation for severity and reaction were recorded together with severity first.

Results and Discussion

Occurrence of stripe rust: The disease was observed in the first week of March 2006 on Morocco in WRSN established at Nowshera followed by Rawalpindi in the second week of March 2006. Heavy and above-average rain showers together with lower than average minimum and maximum temperatures recorded during February and March 2007 contributed significantly to the occurrence of stripe rust.

Due to prevalence of conducive environmental conditions, expression of stripe rust was much earlier in the WRSN established at Nowshera as the disease was detected in the third week of February 2007, while at Rawalpindi during the 1st week of March 2007. At all the WRSN sites, Morocco was the first that expressed susceptibility to stripe rust during both the years.

The results revealed that the intensity of disease infection during 2006-07 was higher as compared to 2005-06. This severity may be attributed to the relative dry weather which prevailed during 2005-06. More rainfalls during 2006-07 favored disease intensity in almost all the commercial varieties. The results are in line with the work done by TeBest *et al*., (2008) who reported that intensity of stripe rust is favored by a model with temperature, humidity and rainfall.

Wheat varietals response to stripe rust: The susceptible cultivar Morocco and Kohistan-97 were the only two cultivars that responded with 80S-90S and 10R-5R reaction, respectively, during 2005-06 and 2006-07 at the WRSN established at Sialkot. No disease was expressed by any other commercial variety at this site during these years. The commercial varieties, Soorab-96 (barley), Tatara (*Yr3*) and GA-2002 were the only three that exhibited resistant response to stripe rust at all the WSRN sites during these two experimentation years (Table 4). The resistant expression of Soorab-96 and GA-2002 is in line with the findings of Rattu *et al*., (2007). There were also 5 cultivars viz-a-viz Pavon-76, Kohsar-93, Fakhr-e-Sarhad, Iqbal-2000 and Durum-97, which showed a combination of resistance and partial resistance responses (Table 4) at the six hot spots.

Table 2. Commercial varieties included in WSRN during 2005-06 & 2006-07.

Sr. no.	Commercial varieties	Yr resistance genes	Year of release	Parentage / Pedigree
1.	Morocco	-	NA	NA
2.	Pavon 76	*Yr29 APR*	1979	VCM//CNO/7C/3/ KAL/BB, CM8399-D-4M-3Y-1M-1Y-1M-0Y-0PAK
3.	MH 97	NA	1998	ATTILA, CM 85836-50Y-0M-0Y-3M-0Y
4.	Inquilab-91	*Yr27*	1991	WL711/CROW 'S' PB1954-9A-1A-0A-0PAK(PAK)
5.	Kohistan 97	NA	1998	V-1562//CHRC 'S'/HORK/3/KUFRA/4/CARP 'S'/BJY 'S' PB24883-B-1A-0A
6.	Punjab 85	NA	NA	KVZ/TRM//PTM/ANA, CM43903-H-4Y-1M-1Y-3M-3Y-0B-0PAK
7.	Bakhtawar 93	*Yr9*	1995	JUP/BJY 'S'//URES
8.	Blue Silver	NA	1971	153-388/AN/3/YT54/N10B//LR64/AN//YT54/ N10B/3/LR864/4/B4946. A.4.18.2.1Y-Y53//3/Y50A.4.18.2.1Y53//3/Y50
9.	Chakwal 86	NA	1986	F1n/ACS//ANA SWM4578-56M-3Y-3M-0Y-0PAK
10.	Sindh-81	NA	1983	NORTENO/MEXIPAK
11.	Zarghoon	*Yr6+*	1979	CC/INIA/3/TOB/CTFN//BB/4/7C CM8237-G-1M-3Y-2M-4Y-0M-OPAK
12.	Faisalabad 83	*Yr7+2 APR*	1983	FURY/KAL/BB CM37138-48Y-1M-5Y-1M-4V-5Y-0A-0PAK
13.	Faisalabad 85	*Yr9 + Yr4*	1985	MAYA/MON//KVZ/TRM CM44083-N-3Y-1M-1Y-1M-1Y-0B
14.	Kaghan 93	*Yr9*	1993	TTR/JUN CM59123-3M-IY-2M-1Y-2M-2Y-0M-0PAK
15.	Kirin 95	NA	NA	NA
16.	Kohinoor 83	*Yr9*	1983	OREF1158/FDL/MFN/2*TIBA63/3/COC CM37987-1-1Y-5M-0Y-0PAK
17.	LU-26	*Yr6*	1976	BLS/KHUSHAL
18.	Nowshera 96	NA	1996	NA
19.	Parwaz 94	*Yr6+Yr7*	1995	V.5648/PRL PBB20089-7A-4A-0A
20.	Pasban 90	NA	1991	INIA F 66/ A DISTCHUM//INIA66/3/GEN
21.	Pirsabak 85	*Yr9*	1985	KVZ/BUHO//KAL/BB CM33027-F-15M-4Y-4M-2Y-1M-1Y-0M-OPAK
22.	Punjab 96	NA	1995	SA42*2/4CC/INIA//BB/3/INIA/HD832 Pb1352-B-4K-36A-0A
23.	Sariab-92	*Yr6+*	1993	BB/GLL//CARP/3/PVN CM33483-C-7M-1Y-0M-OPAK(PAK)
24.	Sarsabz	*Yr7*	1985	M20/79 S89-75-76-RS
25.	Shaheen 94	NA	NA	MLT"S"
26.	Shahkar 95	*Yr6+*	1995	WL711//F3.71/TRM Pb 20371-20A-4A-0A-0K-0A
27.	Soughat 90	*Yr6+Yr7*	1991	PAVON MUTANT-3
28.	Tandojam 83	*Yr6+*	1985	TZPP/PL/7C CM2587-J-1Y-2M-2Y-3M-OY
29.	SH-2002	NA	2002	INQILAB-91/FINK'S' PB.25552-1A-0A-0A-1A-0A.
30.	Pak 81	*Yr9+Yr7*	1981	KVZ//BUHO//KAL/BB CM33027-F-15M-500Y-0M-76B-0Y-0PAK

Table 2. Commercial varieties included in WSRN during 2005-06 & 2006-07.

Sr. no.	Commercial varieties	Yr resistance genes	Year of release	Parentage / Pedigree
31.	Bahawalpur-97	NA	1998	MLT'S' CM47634-1-2M-2Y-1Y-1M-0Y
32.	Kohsar 93	NA	1995	PSN/BOW CM69560-1M-1Y-1M-2Y-0M-0PAK(PAK)
33.	Rohtas 90	*Yr9*	1991	INIA F 66/A.DISTCHUM//INIA66/3/GEN W.8461-R-OPAK(PAK)
34.	Suleman 96	NA	1996	F6.74/BUN//SIS/3/VEE#7 CM86141-62-0Y-0M-4Y-0M
35.	WL 711	*Yr2*	1978	S308/CHRIS//KAL
36.	Zardana	NA	NA	C/CNO67/8156*Tob66-CN067/Nor66/II12300*LR64-8156/PVN76'S;
37.	Abadgar 93	NA	1993	NA
38.	Anmol-91	*Yr9*	1991	KVZ/TRM//PTM/ANA CM43903-H-4Y-1M-1Y-3M-3Y-0B-0PAK
39.	Bahawalpur-2000	NA	2001	NA
40.	Bahkhar-2002	NA	2003	P20102/PIMA/SKA/3/TTR`S'/BOW`S' ,Pb.23826-D-1a-1a-1t-1t-0t.
41.	Fakhr-e-Sarhad	NA	NA	KVZ/BUHO//KAL/BB CM33027-F-15M-500Y-0M087V-0Y
42.	Marvi-2000	NA	2001	CMH-77A917/PKV 1600//RL6010/68SKA
43.	Mehran-89	*Yr9*	1988	KVZ/BUHO//KAL/BB CM33027-F-15M-500Y-0M-87V-0Y
44.	Soorab-96 (Barley)	NA	NA	NA
45.	Tatara	*Yr3*	1999	ATTILA CM85836-50Y-0M-0Y-2M-0Y
46.	Takbeer	NA	1999	NA
47.	AS-2002	NA	2002	KHP/D31708//CN74A370/3/CIAN079/4/RL6043/*4NAC PBD795-23A-1A-0A
48.	Iqbal 2000	*Yr9*	2000	BURGUS/SORT 1213//KAL/BB/3/PAK 81 PB 21912-11A-0A-0A-59A-0A-0A
49.	Auqab-2000	*Yr9*	2000	CROW 'S'/NAC//BOW 'S' PB 222138-3A-0A-0A-231A-0A
50.	Chakwal-97	NA	1998	BUC'S'/FCT'S' CM64663-7M-0Y-0M-7Y-OM.
51.	Durum-97	NA	NA	NA
52.	Watan 94	NA	1994	Lu26/HD2179
53.	Moomal 2002	NA	2002	BUC'S'/4/TZPP//IRN46/CN067/3/PRI-FLAKE-56744 7Y-2Y-1M-1Y-0M
54.	Zarlashata	*Yr9*	2001	URES/BOW`S' CM 78108-1M-02Y-02M-22Y-3B-0Y.
55.	GA-2002	NA	2002	DWL 5023/S N B//SNB CM 84986-H-1M-3M-2B-0Y.
56.	Wafaq-01	*Yr9*	2001	OPATA/RAYON//KAUZ CMBW 90Y3180-0TOPM-3Y-010M-010M-010Y-1M-015Y-0Y.
57.	Margalla-99	NA	1999	OPATA/BOW'S' CM 83398-2M-0Y-0M-5Y-0M
58.	Manthar	*Yr9*	2002	KAUZ//ALTAR84/AOS CM 111633-6M-20Y-10M-10Y-10M-2Y-0M-0B.

NA refers to "Not Available"

Table 3. Field response of host plant against stripe rust.

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

Table 4. Stripe rust reaction of commercial varieties to *Pst* at hot spots of the Northern Punjab and NWFP during 2005-06 & 2006-07.

S. No.	Differential sets	Yr genes	Disease Reaction to *Yr* at Trap nurseries established at											
			PRS (Sialkot)		PMAS-AAU Rwp		NARC (I.abad)		CCRI (Pirsabak)		AUP (Peshawar)		NIFA (Peshawar)	
			05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
1.	Morocco		-	-	-	-	-	-	-	-	-	-	-	-
2.	Pavon 76	*Yr29 APR*	+	+	+	+	**	**	+	+	+	+	+	+
3.	MH 97		+	+	-	-	-	-	-	-	-	-	-	-
4.	Inquilab-91	*Yr27*	+	+	-	-	-	-	-	-	-	-	-	-
5.	Kohistan 97		+	+	-	-	-	-	-	-	+	+	-	-
6.	Punjab 85		+	+	+	**	**	-	-	-	-	-	-	-
7.	Bakhtawar 93	*Yr9+*	+	+	-	-	-	-	-	-	+	+	-	-
8.	Blue Silver	*Yr6+A*	+	+	-	-	-	?	-	-	+	**	-	-
9.	Chakwal 86		+	+	-	-	-	-	-	-	+	+	-	-
10.	Sindh-81		+	+	-	-	-	-	-	-	-	-	-	-
11.	Zarghoon	*Yr6+*	+	+	-	-	-	-	-	-	-	-	-	-
12.	Faisalabad 83	*Yr7+ 2 APR*	+	+	-	-	-	-	-	-	-	-	-	-
13.	Faisalabad 85	*Yr9+ Yr4*	+	+	-	-	-	-	-	-	-	-	-	-
14.	Kaghan 93		+	+	-	-	-	-	-	-	-	-	-	-
15.	Kirin 95		+	+	-	-	-	-	-	-	-	-	-	-
16.	Kohinoor 83		+	+	-	-	-	-	-	-	-	-	-	-
17.	LU-26	*Yr6*	+	+	-	-	-	-	-	-	-	-	-	-
18.	Nowshera 96		+	+	-	-	-	-	-	-	-	-	-	-
19.	Parwaz 94	*Yr6+ Yr7*	+	+	-	-	-	-	-	-	+	+	-	-
20.	Pasban 90		+	+	-	-	-	-	-	-	+	+	-	-
21.	Pirsabak 85		+	+	-	-	-	-	-	-	+	+	-	-
22.	Punjab 96		+	+	-	-	-	-	-	-	-	-	-	-
23.	Sariab-92	*Yr6+*	+	+	-	-	-	-	-	-	-	-	-	-
24.	Sarsabz	*Yr7*	+	+	-	-	-	-	-	-	-	-	-	-
25.	Shaheen 94		+	+	-	-	-	-	-	-	+	-	-	-
26.	Shahkar 95	*Yr6+*	+	+	**	-	-	-	-	-	+	**	-	-
27.	Soughat 90	*Yr6+ Yr7*	+	+	-	-	-	-	-	-	**	**	-	-
28.	Tandojam 83	*Yr6+*	+	+	-	-	-	-	-	-	-	-	-	-
29.	SH-2002		+	+	-	-	-	-	-	-	-	-	-	-

Table 4. (Cont'd.).

S. No.	Differential sets	Yr genes	Disease Reaction to *Yr* at Trap nurseries established at											
			PRS (Sialkot)		PMAS-AAU Rwp		NARC (I.abad)		CCRI (Pirsabak)		AUP (Peshawar)		NIFA (Peshawar)	
			05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
30.	Pak 81	*Yr9+Yr7*	+	+	-	-	-	-	-	-	-	-	-	-
31.	Bahawalpur-97		+	+	-	-	-	-	-	-	-	-	-	-
32.	Kohsar 93		+	+	+	+	**	+	**	**	+	+	**	**
33.	Rohtas 90		+	+	-	-	-	-	-	-	-	-	-	-
34.	Suleman 96		+	+	-	-	-	-	-	-	-	-	-	-
35.	WL 711	*Yr2*	+	+	-	-	-	-	-	-	-	-	-	-
36.	Zardana	*Yr7*	+	+	-	-	-	-	-	-	-	-	-	-
37.	Abadgar 93		+	+	-	-	-	-	-	-	-	-	-	-
38.	Anmol-91	*Yr9*	+	+	-	-	-	-	-	-	+	-	+	+
39.	Bahawalpur-2000		+	+	-	-	-	-	-	-	+	+	-	-
40.	Bahkhar-2002		+	+	-	-	-	-	+	+	+	-	+	+
41.	Fakhr-e-Sarhad		+	+	+	+	+	+	**	**	**	+	**	**
42.	Marvi-2000		+	+	+	+	+	**	-	-	-	-	-	-
43.	Mehran-89	*Yr9*	+	+	-	-	-	-	+	-	+	**	+	+
44.	Soorab-96 (Barley)		+	+	+	+	+	+	+	+	+	+	+	+
45.	Tatara	*Yr3*	+	+	+	+	+	+	+	+	+	+	+	+
46.	Takbeer		+	+	-	-	+	-	+	**	+	-	+	-
47.	AS-2002		+	+	-	-	+	-	+	-	+	**	+	+
48.	Iqbal 2000	*Yr9*	+	+	+	+	+	+	**	**	+	+	+	+
49.	Auqab-2000	*Yr9*	+	+	**	**	**	**	+	+	**	-	-	-
50.	Chakwal-97		+	+	-	-	-	-	-	-	+	**	**	**
51.	Durum-97		+	+	+	**	**	+	+	+	+	+	+	+
52.	Watan 94		+	+	-	-	-	-	-	-	-	-	-	-
53.	Moomal 2002		+	+	-	-	-	-	-	-	-	-	-	-
54.	Zarlashta	*Yr9*	+	+	-	-	-	-	-	-	+	-	+	+
55.	GA-2002		+	+	+	+	+	+	+	+	+	+	+	+
56.	Wafaq-01	*Yr9*	+	+	-	-	-	-	-	-	+	-	-	-
57.	Margalla-99		+	+	-	-	-	-	-	-	-	-	-	-
58.	Manthar-3	*Yr9*	+	+	-	-	-	-	-	-	+	+	-	-

+ = Resistant, - = Susceptible, ** = Partial Resistance, ? = Missed entry

Among the commercial wheat cultivars included in the nurseries, MH-97, Inquilab-91, Sindh-81, Zargoon, Faisalabad-83, Faisalabad-85, Kaghan-93, Kirin-95, Kohinoor-83, LU-26, Nowshera-96, Punjab-96, Sariab-92, Sarsabz, Tandojam-83, SH-2002, Pak-81, Bahawalpur-97, Rothas-90, Suleman-96, WL-711, Zardana, Abadgar-93, Watan-94, Moomal-2002 and Margalla-99 exhibited susceptible reactions at all locations except at Sialkot (Table 4). Contrarily, Kohistan-97, Punjab-85, Bakhtawar-93, Blue Silver and Chakwal-86 bestowed mix response from resistant to partial resistant and even susceptible reactions at the WSRNs during 2005-06 and 2006-07. Chakwal-86 was the single variety that presented MRMS type reaction at all the WSRN sites during these years (Table 5).

Table 4 exposes 8 wheat commercial varieties viz., Kohistan-97, Bakhtawar-93, Chakwal-86, Parwaz-94, Pasban-90, Pirsabak-85, Bahawalpur-2000 and Manthar-3 as completely resistant to stripe rust only at the WSRN site in Peshawar (AUP) and Sialkot (PRS) during 2005-06 and 2006-07.

Field data illustrated that majority of the *Yr* resistance genes showed susceptible reaction at all WSRN locations and expressed 5–100S yellow rust reaction in Morocco, Inquilab-91 (*Yr*27), Bakhtawar-93 (*Yr*9+), Wafaq-01 (*Yr*9) and MH-97 during both the years (Table-5) but exhibited immune reaction at Sialkot. However, Bakhtawar-93 offered 20-30MS at AAUR, 30MRMS-40S at NARC, 20S at CCRI and 50MSS-50S at NIFA during 2005-06 and 2006-07, respectively (Table-5). No susceptibility for this variety was observed during these years at AUP. Wafaq-01 showed 20S at UAAR and NARC, while 40MS at CCRI and 30S at NIFA whereas MH-97 revealed 30-80S response at the WRSN sites during 2005-06 and 2006-07 (Table 5).

The variety Blue Silver (*Yr6+YrA*), which demonstrated susceptibility at four WSRN sites, expressed resistance at Peshawar (AUP) during 2005-06 while showed partial resistance in 2006-07. Likewise, Soghat-90 (*Yr6+Yr7*) offered susceptibility at all the nursery sites excluding Sialkot but remained partially resistant at Peshawar (AUP) during 2005-06 and 2006-07. Mehran-89 (*Yr9*) and AS-2002 showed all types of reactions including resistance, partial as well as susceptible responses at various locations during the experimentation years.

There were few commercial varieties in the trials like Punjab-85 at Islamabad, Shahkar-95 at Rawalpindi while Shaheen-94 and Auqab-2000 at Peshawar that showed resistance or partial resistance during 2005-06 but expressed susceptibility in the following year. This suggests that virulence was not present or if present, was not effective enough to overcome resistance. In the following year resistance seems to collapse and this short term resistance failure led to a boom-and-bust syndrome (Kilpatrick, 1975).

Among the wheat rust resistance breeding programs, few achievements have, however, been seen for some years as 1BL.1RS wheat-rye translocation (Zeller, 1973), linked with *Yr9, Lr26, Sr31* and *PM8* remained effective throughout the wheat world till 1999. Presently, this translation is available in a number of high yielding wheat cultivars, including Faisalabad-85 and Pak-81. Although virulence is prevailing to *Yr9* at the NWFP, however, some cultivars like Anmol-91, Zarlashta and Wafaq-01, known to possess *Yr9,* showed resistant response during 2005-06 at Peshawar (AUP) but exhibited susceptibility at the same site during 2006-07 (Table 4).

Table 5. Reaction of commercial varieties to stripe rust at hot spots of the Northern Punjab & NWFP during 2005-06 & 2006-07.

S. No.	Differential sets	Yr genes	Wheat stripe rust nurseries established at											
			PRS (Sialkot)		PMAS-AAU Rwp		NARC (Labad)		CCRI (Pirsabak)		AUP (Peshawar)		NIFA (Peshawar)	
			05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
1.	Morocco		80S	90S	80S	100S	100S	100S	90S	90S	90S	100S	100S	100S
2.	Pavon 76	*Yr29 APR*	0	0	5MS	5MS	10MS	10MS	0	0	0	0	0	0
3.	MH 97		0	0	60S	70S	70S	80S	30S	60S	80S	40S	60S	50S
4.	Inquilab-91	*Yr27*	0	0	30S	40S	40S	50S	50S	50S	30S	40S	30S	30S
5.	Kohistan 97		10R	5R	80S	80S	30S	40S	60S	30S	0	0	40S	50S
6.	Punjab 85		0	0	5MRMS	10MS	10MS	20S	50S	40S	10S	40S	80S	70S
7.	Bakhtawar 93	*Yr9+*	0	0	20MS	30MS	30MRMS	40S	20S	20S	0	0	50MSS	50S
8.	Blue Silver	*Yr6+A*	0	0	50S	80S	60S	Missed	30S	20S	0	10MRMS	50S	40S
9.	Chakwal 86		0	0	30MRMS	40MRMS	20MRMS	20MRMS	30MRMS	40MRMS	0	5MRMS	40MRMS	20MRMS
10.	Sindh-81		0	0	50S	70S	40S	50S	40MRMS	30S	20MSS	30MSS	60S	50S
11.	Zarghoon	*Yr6+*	0	0	10MSS	10S	60S	40S	70S	40S	10S	20S	50S	40S
12.	Faisalabad 83	*Yr7+2 APR*	0	0	50S	80S	60S	80S	30S	70S	10MSS	20MSS	60S	70S
13.	Faisalabad 85	*Yr9+ Yr4*	0	0	20S	30S	50S	50S	60S	60S	10MSS	10MSS	40MRMS	40MS
14.	Kaghan 93		0	0	90S	60S	70S	40S	60S	30S	10MSS	10MSS	60S	50S
15.	Kirin 95		0	0	90S	80S	80S	60S	70S	40S	20MS	30MS	80S	50S
16.	Kohinoor 83		0	0	80S	60S	60S	50S	90S	40S	20MS	30MS	70S	60S
17.	LU-26	*Yr6*	0	0	70S	60S	80S	40S	50S	40S	20MSS	40MSS	60S	70S
18.	Nowshera 96		0	0	50MSS	30S	50S	40S	50S	20S	10MSS	20MSS	60S	60S
19.	Parwaz 94	*Yr6+ Yr7*	0	0	20MSS	20MSS	40MSS	10S	40MSS	20MS	0	TRMR	10MSS	20MSS
20.	Pasban 90		0	0	50S	50S	30MSS	20S	70S	20S	0	TR	60S	60S
21.	Pirsabak 85		0	0	80S	60S	80S	50S	60S	40S	0	TR	60S	40S
22.	Punjab 96		0	0	80S	50S	60S	60S	80S	50S	10MSS	10MSS	50S	60S
23.	Sariab-92	*Yr6+*	0	0	80S	80S	80S	70S	50S	60S	20S	40S	60S	70S
24.	Sarsabz	*Yr7*	0	0	80S	70S	60S	60S	50S	70S	10S	20S	60S	50S
25.	Shaheen 94		0	0	80S	60S	30MSS	30S	40S	40S	0	10MSS	50S	40S
26.	Shahkar 95	*Yr6+*	0	0	10MS	20MS	30MRMS	10S	40MRMS	30S	0	10MRMS	50MRMS	40MRMS
27.	Soughat 90	*Yr6+ Yr7*	0	0	10S	10S	10S	10S	10S	10S	10MS	10MS	40S	40S
28.	Tandojam 83	*Yr6+*	0	0	100S	60S	80S	70S	60S	70S	40S	50S	60S	50S
29.	SH-2002		0	0	90S	60S	70S	60S	40MSS	40S	60S	50S	60MSS	50S

Table 5. (Cont'd.).

S. No.	Differential sets	Yr genes	Disease Reaction to *Yr* at Trap nurseries established at											
			PRS (Sialkot)		PMAS-AAU Rwp		NARC (Labad)		CCRI (Pirsabak)		AUP (Peshawar)		NIFA (Peshawar)	
			05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07	05-06	06-07
30.	Pak 81	*Yr9+ Yr7*	0	0	70S	50S	60S	50S	60S	40S	40S	60S	70S	50S
31.	Bahawalpur-97		0	0	40S	30S	40S	30S	60S	20S	40S	40S	60MSS	40MSS
32.	Kohsar 93		0	0	0	0	10MRMS	0	10MS	5MS	0	TR	10MS	5MSS
33.	Rohtas 90		0	0	10MSS	30MSS	40S	50S	20MSS	40S	10S	20S	10MSS	10MSS
34.	Suleman 96		0	0	50S	50S	70S	30S	60S	30S	10MSS	20MSS	70S	60S
35.	WL 711	*Yr2*	0	0	80S	70S	60S	70S	80S	70S	10S	40S	70S	50S
36.	Zardana	*Yr7*	0	0	80S	80S	80S	40S	50S	30S	10S	40S	40S	50S
37.	Abadgar 93		0	0	40S	50S	60S	30S	40S	30S	10MSS	30MSS	50S	60S
38.	Anmol-91	*Yr9*	0	0	50S	50MS	60MSS	40S	30MSS	40S	0	20MSS	5MRMS	5MRMS
39.	Bahawalpur-2000		0	0	20MSS	20MSS	30S	10S	50S	20S	5MSS	5MSS	50S	60S
40.	Bahkhar-2002		0	0	70S	40MRMS	80S	30MRMS	0	5MRMS	0	20MSS	0	0
41.	Fakhr-e-Sarhad		0	0	0	0	0	5MS	10MS	10MS	10MS	5MS	10MS	10MS
42.	Marvi-2000		0	0	0	TR	0	10MS	20S	10S	20S	10S	30S	40S
43.	Mehran-89	*Yr9*	0	0	70S	50S	40S	50S	0	30S	0	5MS	0	0
44.	Soorab-96 (Barley)		0	0	TR	TR	0	0	0	0	0	0	0	0
45.	Tatara	*Yr3*	0	0	0	0	TR	0	0	TMR	0	TMS	0	5RMR
46.	Takbeer		0	0	70S	50MS	0	10S	0	10MS	0	40MS	0	40MSS
47.	AS-2002		0	0	20MSS	20MS	0	10S	0	30MSS	0	5S	0	TR
48.	Iqbal 2000	*Yr9*	0	0	0	0	0	0	10MS	10MS	0	TR	0	TR
49.	Auqab-2000	*Yr9*	0	0	10MRMS	10MRMS	20MR	20MR	10MR	0	10MS	30MS	20MSS	30MSS
50.	Chakwal-97		0	0	70S	50S	60MSS	50S	50MSS	30MSS	0	10MRMS	10MRMS	10MRMS
51.	Durum-97		0	0	10MR	20MR	20MR	TR	0	TR	0	5R	0	5R
52.	Watan 94		0	0	20MSS	20MS	50MSS	20S	20MSS	30MSS	10MSS	20MSS	50S	50S
53.	Moomal 2002		0	0	80S	80S	70S	60S	60S	20S	20S	40S	30MSS	40MSS
54.	Zarlashta	*Yr9*	0	0	10S	30S	40MSS	50S	30S	20MS	0	10MSS	0	10MR
55.	GA-2002		0	0	TR	TR	0	0	TR	0	0	0	TR	TR
56.	Wafaq-01	*Yr9*	0	0	20S	20S	20S	20S	40MS	40MS	0	10S	30S	30S
57.	Margalla-99		0	0	60S	60S	70S	60S	70S	80S	30S	60S	30S	50S
58.	Manthar-3	*Yr9*	0	0	20S	30S	30MSS	20S	10MSS	10S	0	5MRMS	20MRMS	20MSS

The commercial varieties in Pakistan that encompass the range between MRMS to MSS type reaction might eventually express susceptibility after appearance of virulence. The genes, *Yr6, Yr7* and *Yr9* are the most frequently encountered stripe rust resistance gene either alone or in a blend with other *Yr* genes, present in the commercial Pakistani wheat varieties while Inquilab-91 possesses *Yr27* resistance gene. The commercial cultivars SH-2002 and Bakhtawar that were found resistant to the race group collection of 2003-04 (Ahmad & Kazi, 2005) proved a contrary situation when tested under this study during 2005-06 and 2006-07. SH-2002 and Bakhtawar-93 was found resistant at Sialkot and Peshawar (AUP), respectively during the experimentation years, while expressed susceptibility at other WSRNs. The commercial cultivar Marvi-2000 is worth to be mentioned here as it showed resistant response (Rattu *et al.,* 2007) and also expressed no disease reaction at WSRN Sialkot (2005-06 and 2006-07), Rawalpindi and Islamabad during 2005-06. The variety Marvi-2000 exhibited TR to 10MS type disease reaction at Rawalpindi and Islamabad, respectively during the following year and a susceptible type reaction ranging from 10-40S at the WRSN sites in the NWFP during both the experimentation years (Table 5). This is indicative of the fact that stripe rust pathotypes have the potential to overcome resistance with time and accordingly have rendered the variety susceptible, which was considered to be resistant earlier on.

The unwavering race composition could be due to few wheat varieties that are extensively cultivated over the years with similar genetic background as the previous wheat breeding programs have not generally been concerned with the resistance to stripe rust. After the dawn of new millennium, the race composition has become a complex due to introduction of a number of wheat cultivars such as SH-2002, Bahawalpur-2000, Bahkhar-2002, Marvi-2000, AS-2002, Iqbal-2000, Auqab-2000, Moomal-2002, Zarlashata, GA-2002, Wafaq-01 and Manthar.

An unnamed slow rusting gene in combination with *Lr46* is responsible for the Pavon-76 slow rusting resistance (Singh *et al.,* 1998), is currently believed to possess durable resistance (Singh & Rajaram, 1994). Although the adult plant genes *Yr29* present in cultivar Pavon-76 showed MS type reaction only at Rawalpindi and Islamabad, it might still have relative level of resistance compared with other susceptible varieties cultivated in Pakistan. It can, therefore, still be used as a potential cultivar and the responses are expected to provide adequate crop protection. It can, therefore, be concluded that few of the varieties still have potential to be used as a source of resistant germplasm against the stripe rust disease. However, we should not solely rely upon Inquilab-91 as it has shown greater susceptibility than the previous years (Afzal *et al.,* 2008).

The key to control cereal rusts is to use resistant cultivars (Johnson, 1981). The cultivars remain resistant to rust for five or a bit more years depending upon the agronomic lifespan, when a lively breeding program subsists. Some varieties fell to rust as soon as they are cultivated. Most of such cases are attributed to the failure that happen due to inadequate knowledge about the prevailing virulences in the pathogen population. In some instances, mutations or possibly recombination in existing virulences render the wheat crop susceptible.

A quest for hunting new and efficient sources of stripe rust resistance genes is imperative to tangle the alteration in the host-pathogen interaction. In Pakistan, *Yr27* was not widely used in commercial wheat cultivars and due to this reason Inquilab-91 survived for the longest period in the major stripe rust zone of the Northern Punjab and NWFP till 2003-04. These previously resistance genes now lack sufficient protection against prevailing stripe rust pathotypes in the northern areas of Pakistan. Non-

replacement of these cultivars by the ones with more effective genes would endanger the golden grains harvest in an ample quantity.

The epidemics that witnessed during 1977-78 and 1992-93 cautions that stripe rust could be a serious threat for wheat in Pakistan whenever the pre-requisites of disease triangle is accomplished. Production losses associated with the disease (Afzal *et al*., 2008) and non-affording of high input costs due to the repeated fungicidal application necessitate the development of sustainable control measures against stripe rust. Under the present growing circumstances of predominantly dry-land wheat production coupled with uncertain rainfall, breeding for resistant cultivars is emphasized which will offer the most reliable and cost-effective channel for controlling stripe rust. Effective breeding approach, therefore, strongly relies upon the understanding of genetic variation in both host and pathogen. Effective disease control approach further necessitates an epidemiological understanding of the pathogen. This includes the potential of stripe rust pathogen to persist during non-crop season and disease occurrence probability in different wheat-cultivated areas of the Northern Punjab and NWFP. The same will have a restraining influence on the release of cultivars that are susceptible in hot spot areas, which will be an important aspect in selection of a cultivar by the farmers.

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