MEHTAENSIS

(मेहतांसिस)

Prof. K.C. Mehta (1892-1950)

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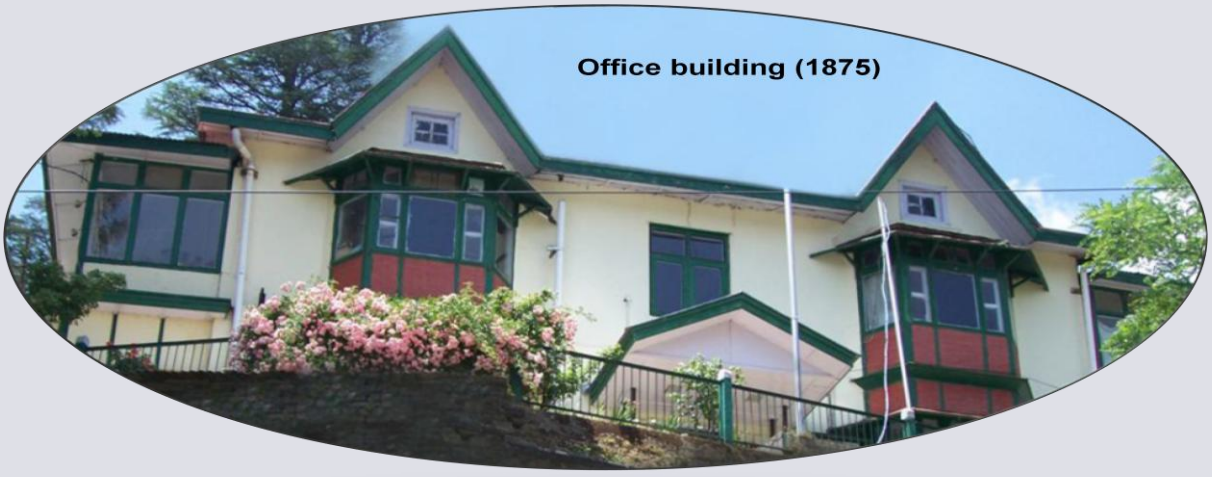

1. Executive summary/कार्यकारी सारांश

इस वर्ष (2014–15) रतुआ रोग पिछले वर्ष की अपेक्षा देर से देखे गये तथा इनकी तीव्रता भी कम रही। इस अवधि के दौरान, 1269 गेहूँ एवं जौ के रतुआ नमूनों का विश्लेषण किया गया। रतुआ नमूनों के विश्लेषण में सात नये प्रभेदों की पहचान की गयी। पीला रतुआ के पांच नये प्रभेदों को 46एस117, 110एस119, 110एस247, 238एस119 और 110एस84 के रूप में नामांकित किया गया। इनमें प्रभेद 110एस119 सर्वाधिक नमूनों (12 प्रतिशत) में पाया गया। गैर पीबीडब्ल्यू343 किस्मों के क्षेत्रफल में वृद्वि विशेष रूप से एचडी 2967 तथा ठंडा आर्द्र वातावरण होने के कारण पीले रतुआ/रतुवा का प्रभेद 46एस119 बहुतायत में पाया गया। इस प्रभेद की आवृत्ति 70% रही जबकि प्रभेद 78एस84 केवल 3% नमूनों में पाया गया। भूरे और काले रतुए के प्रभेद क्रमशः 121आर60–1 (77–9) और 79जी31(11) सर्वाधिक अनुपात में पाये गए। गेहूँ एवं जौ की 2310 लाइनों में, रतुआ प्रतिरोधी लाइनों का पता लगाने के लिए इनका का मुल्यांकन शीशगृह में उग्र प्रभेदों के विरूद्व किया गया। गेहूँ की कोई भी लाइन/ किस्म तीनों रतुओं के लिए प्रतिरोधी नहीं पाई गई जबकि जौ में, एनबीडीएसएन की 09 और इबीडीएसएन की 03 किस्में सभी जौ रतुओं के लिए प्रतिरोधी पायी गयीं। गेहूँ की एवीटी I एवं II की 173 लाइनों में 09 एलआर, 05 वाईआर तथा 14 एसआर जींस अभिधारणित किये गये। गेहूँ, जौ, जई और अलसी के विभिन्न रतुआ प्रभेदों का रख–रखाव किया गया और आवश्यकतानुसार इनमें से कुछ प्रभेदों के रतुआ रोग पर कार्य करने वाले 20 वैज्ञानिकों/केन्द्रो को अनुसंधान कार्य के लिए भेजा गया। गेहूँ की विभिन्न बिमारियों तथा उनके फैलने की निगरानी हेतु गेहूँ रोग परीक्षण नर्सरी देश में 43 स्थानों तथा इसके अतिरिक्त सार्क देशों में भी लगाई गयीं तथा इनमें गेहूँ के रतुआ रोगों की स्थिति की समीक्षा की गयी।

There was no major outbreak of wheat rusts in India during 2014-15 crop season. Yellow rust appeared one month late and the incidence of yellow rust of wheat was low at all the locations in Northern India. Yellow rust remained under threshold level as area and diversity of yellow rust resistant varieties has increased and a vigil was also kept by IIWBR/ICAR, SAUs and the State department of Agriculture against any outbreak. During 2014-15, 1269 samples of different rusts of wheat and barley were received/ collected for pathotype analyses. Analyses of more than 790 samples revealed that the wheat yellow rust population analyzed is avirulent to *Yr*5, *Yr*10, *Yr*13, *Yr*14, *Yr*15, *Yr*26, *Yr*Sp and *Yr*Sk ; black rust to *Sr* 26, *Sr* 27, Sr 31, *Sr* 32, *Sr* 35, *Sr*39, *Sr* 40, *Sr* 43, *Sr*Tt3 and *Sr* Tmp ; and that of brown rust to *Lr*24, *Lr*25, *Lr*29, *Lr*32, *Lr*39, *Lr*42 and *Lr*45. Seven new pathotypes; five in

yellow rust and two in brown rust of wheat were identified. Five new pathotypes of *Puccinia striiformis* have been designated as 46S117, 110S119, 238S119, 110S247 and 110S84. Among these pathotype 110S119 was most common and was identified in about 12% samples. Most of the yellow rust pathotypes are progressive mutations in the existing pathotypes and are more aggressive. *Yr*11, *Yr*12 and most probably *Yr*24, which used to be resistant to yellow rust in India, have been rendered susceptible. Among the 9 lines of AVTI, which were resistant to yellow rust, seven have become susceptible to one or more of the new pathotypes. Further studies on these pathotypes are being conducted. Owing to the increase in area under non PBW343 varieties especially HD2967, pt. 46S119 of *Puccinia striiformis* (yellow/stripe rust of wheat) remained predominant and was identified in 70% samples whereas pt. 78S84 occurred only in 3% of the samples. In *P. triticina* (brown/leaf rust of wheat) the proportion of pt. 77-9 (121R60-1=MHTKP) was more than that of pt. 77-5 (121R63-1=THTTM) and it was the most predominant in Karnataka, Madhya Pradesh and Punjab. In *P. graminis tritici* (black/stem rust of wheat) pathotype 11 (79G31=RRTSF) was most widespread, frequent and observed in 51% samples followed by pt. 21-1 (24G5=CKMSC). **Virulence on *Sr*31 (Ug99 type of pathotypes) were not identified anywhere in India, Bangladesh, Bhutan and Nepal**. For identifying the rust resistant sources in AVT, NBDSN, EBDSN and breeder's material, 2310 lines of wheat and barley were evaluated against the virulent pathotypes of all three rust. In advance wheat material (173), none of the lines was resistant to all the rusts. Nine lines in NBDSN and three in EBDSN were resistant to all the barley rusts. Rust resistance genes were characterized in AVT I and II wheat material. Proportion of lines with *Yr*9/*Lr*26/*Sr*31 has reduced further . Five *Yr* genes (*Yr*2, A, 9, 18 and 27) were characterized in 47 lines of AVT II and three genes (*Yr*2, A and 9) in 67 lines of AVT I. Eleven *Sr* genes were inferred in 65 lines of AVT II whereas 14 *Sr* genes were postulated in 99 lines of AVT I. Nine *Lr* genes were characterized in each 60 and 87 lines of AVT II and I, respectively. More than 126 pathotypes were maintained as live cultures as well as cryo-preserved. Nucleus and bulk inocula were supplied to 20 Scientists/ centre during Jan-June, 2015. Three genetic stocks were characterized for stem rust resistance and yield components. Basic molecular studies on wheat rust pathotypes

were undertaken. To monitor the occurrence and spread of wheat diseases, Wheat disease monitoring nursery in India and SAARC nursery were coordinated.

2. Incidence of wheat rusts in India

The weather remained cool during this crop season. Although, the yellow rust was reported much around 20th December, 2014 from Daroli village in Ropar district of Punjab, nevertheless, there were no major incidence. Comparatively the incidence of yellow rust was low. Brown rust was widely distributed in different wheat growing areas of India. Black rust was reported in Gujarat, Uttrakhand, Madhya Pradesh, Maharashtra and Tamil Nadu. In nutshell there was no major incidence of wheat rusts in India during 2014-15 crop season. Role of grasses in wheat rust epidemiology is also being studied, so far none of the rust samples from grasses could infect wheat, barley and oat.

3. Monitoring and sample collection of wheat and barley rusts

During 2014-15, a total of 1269 samples of three rusts of wheat and yellow rust of barley were collected/ received from eleven states of India, Bangladesh, Bhutan and Nepal (Table 1). To monitor pathotype situation of wheat and barley rusts effectively, many researchers have surveyed their areas effectively and sent rust samples to Flowerdale. Notably, 43 Scientists have contributed in this national endeavour to combat wheat and barley rusts. Cooperating Scientists are listed in Table 2.

Table 1: Details of wheat and barley rust samples collected/ received during 2014-15

S. No.	States/ Countries	Wheat			Barley		
		Yellow	Brown	Black	Yellow	Brown rust	Black rust
1.	Tamil Nadu	13	72	34	-	-	-
2.	Maharashtra	-	38	07	-	-	
3.	Karnataka	-	120	-	-	-	-
4.	Gujarat	-	05	24	-	-	-
5.	Madhya Pradesh	-	31	07	-	-	
6.	Punjab	101	19	-	-	-	-
7.	Haryana	32	09	-	-	-	-
8.	Rajasthan	37	-	-	01	-	-
9.	Uttarakhand	101	32	28	03	-	-
10.	Himachal Pradesh	256	16	-	06	-	-
11.	Jammu & Kashmir	91	01	06	-	-	-
Other countries							
1.	Nepal	72	48	-	05	-	-
2.	Bangladesh	-	39	-	-	-	
3.	Bhutan	07	08	-	-	-	-
Total		**710**	**438**	**106**	**15**	-	-

Table 2: List of actively involved co-operators in monitoring wheat and barley rusts during 2014-15

Organization	Co-operators
Regional Station, ICAR- IARI, Wellinton, TN	M Sivaswamy, P Nallathambi, VK Vikas
Regional station, ICAR-IARI, Indore, MP	TL Parkash,
Regional station, ICAR-IARI, Shimla, HP	D P Walia, J Kumar
ICAR-IARI, Pusa, New Delhi	Vaibhav Singh
Agharkar Research Institute, Pune, MH	BK Honrao, VM Khade
NARC and CIMMYT, Nepal	Sarala Sharma, BN Mahto, Vinay Prasad
RARS, BARI, Jessore, Bangladesh	PK Malaker
Bhutan	Sonam Dorji
Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan	Pradeep Shekhawat
ICAR-IIWBR, Karnal, Haryana	MS Saharan, Sudheer Kumar, R Selvakumar, V Tiwari
Hill Agril. Research & Extension Centre, CSKHPKV, Bajaura, Kullu, HP	Rakesh Devlash
Hill Agril. Research & Extension Centre, CSKHPKV, Dhaulakuan, Sirmaur, HP	Dhanvir Singh
Rice and wheat research station, CSKHPKV, Malan, Kangra, HP	SK Rana
KVK, CSKHPKV, Hamirpur, HP	Anand Singh
MAREC, CSKHPKV, Sangla, Kinnaur, HP	Surendra K Sharma
GBPUAT, Pantnagar, US Nagar, UK	Deep Shikha
SKUAST, Jammu, J&K	MK Pandey, Vishal Gupta, Inder Singh
SKUAST-K, Wadura Sopore, J&K	Mohd Anwar Khan
KVK, SKUAST-K, Leh, J&K	Vikas Gupta
MFCRC, SKUAST-K, Khudwani, J&K	Mohd Najeeb Mughal
SDAU, Vijapur, Mehsana, Gujarat	AA Patel, SS Patel
PAU, Ludhiana, Punjab	Jaspal Kaur
MAHYCO, Jalna, MH	M Prashar
ICAR-VPKAS, Almora, UK	SK Jain
CCSHAU, Hisar, Haryana	SS Karwasra, Bhagat singh
NDUAT, Faizabad, UP	SP Singh
Eternal University, Baru sahib, Sirmaur, HP	HS Dhaliwal
UAS, Dharwad, Karnataka	PV Patil
ARS, MPKV, Niphad, Nashik, MH	BC Game
BARC, Mumbai	BK Das

4. Pathotype distribution of *Puccinia* species on wheat and barley during 2014-15

During this period, 799 samples of three rusts of wheat and yellow rust of barley were analyzed from eleven states of India and three neighboring countries.

a. Yellow rust of wheat & Barley (*Puccinia striiformis*)

Total 341 yellow rust samples of wheat and barley were analyzed for understanding the pathotypic diversity, distribution and identifying new virulence at initial stage, if any. The maximum samples were analyzed from Himachal Pradesh (147) followed by Jammu & Kashmir. With an increase in area under non PBW343 varieties especially HD2967, the virulence frequency favoured *Yr*9 virulent pt. 46S119 with highest (70%) proportion among the ten pathotypes identified. Frequency of PBW343 virulent pt. 78S84 has dropped further to 3% (Table 3) from 32% in 2011-12. With the identification of 5 new pathotypes, Indian population of yellow rust is avirulent to *Yr*5, *Yr*10, *Yr*13, *Yr*14, *Yr*15, *Yr*26, *Yr*Sp and *Yr*Sk. Other pathotypes P, CI, 7S0 and T were observed in few samples only. The pt. 46S119 was identified in all the rust samples received and analyzed from Nepal and Bhutan.

Prevalence of barley yellow rust was negligible during the year. In barley yellow rust pathotype M and 57 were observed in ten samples from Himachal Pradesh and Jammu and Kashmir, Uttarakhand, Rajasthan and Nepal. The frequency of pt. M (1S0) was higher than the pt. 57 (0S0).

New pathotypes

Five new pathotypes were recorded in the remaining samples. These new pathotypes have more virulence than the existing pathotypes and appear to be mutation in the existing pathotypes on Suwon x Omar and Riebesel 47/51. These new pathotypes have been designated as 46S117, 110S119, 238S119, 110S247 and 110S84. Among these pathotype 110S119 was most common and was identified in about 13% samples. *Yr*11, *Yr*12 and most probably *Yr*24, which used to be resistant to yellow rust in India, have been rendered susceptible. Among the 9 lines of AVTI, which were resistant to yellow rust, seven have become susceptible to one or more of the new pathotypes. Further studies on these pathotypes are being conducted.

b. Brown rust of wheat (*Puccinia triticina*)

Twenty five pathotypes were identified in 379 samples received from 9 states of India and three neighboring countries. There was a shift in virulence pattern with pathotype 77-9 (MHTKP) becoming more frequent in Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh and Punjab. Three predominant pathotypes i.e. 77-9=MHTKP (38%), 77-5=THTTM

(32%) and 104-2 (14%) comprised of 85% of the flora. Among these, both pathotypes 77-5 (THTTM) and 104-2 (PHTTL) occurred in eight states of India and three neighboring countries. Pathotype 77-9 was observed only in seven states of India but not in the neighboring countries. Remaining 22 pathotypes occurred in few samples only (Table 4).

New pathotype

Two new pathotypes designated as 107-2 and 20-1 were identified. These are less virulent than the existing pathotypes and do not have any epidemiological consequence. Further studies are being undertaken.

Black rust of wheat (*Puccinia graminis* f. sp. *tritici*)

Seventy two samples were analyzed from six states of India. Among the eight pathotypes identified in black rust samples, pathotype 11(RRTSF) was observed in more than 50% of the samples followed by 40A (PTHSC) and 21-1=CKMSC (Table 2). Remaining pathotypes were identified in few samples only (Table 5). Characteristic feature of this analysis was the predominance of pathotype 11 instead of pathotype 40A which used to be the predominant during the previous years. **Virulence on *Sr*31 (Ug99 type of pathotypes) were not identified anywhere in India , Bangladesh , Nepal and Bhutan.**

5. Seedling resistance test in wheat against rust pathotypes

To identify rust resistant lines of wheat and characterize rust resistance genes, 173 lines of AVT I and II were evaluated at seedling stage using an array of pathotypes of black (*P. graminis tritici*), brown (*P. triticina*) and yellow rust (*P. striiformis*) having different avirulence/virulence structures. None of the lines was resistant to all the rusts. Three lines of AVT II and one line of AVT I exhibited resistance to the two rusts. In addition to all the lines having *Sr*31 were resistant to black rust of wheat, whereas lines possessing *Lr*24, some with *Lr*26 were resistant to brown rust and few lines with *Yr*9 showed resistance to yellow rust of wheat. Details of the wheat rust resistant lines are given below:

AVT II year

Resistant to black and brown rusts: HI1563(C), PBW723

Resistant to black and yellow rusts: HD3043(C)

Resistant to yellow rust only: HD3059(C), MACS3927 (D)

Resistant to black rust only: HD2932(C), HI1544(C),TL2942(C), TL2969(C)

Resistant to brown rust only: HD2684(C), HD4728(D), HI4730(D), MACS6222(C), NIAW2030, UAS446 (D) (C)

AVT I year

Resistant to black and brown rusts: HPBW09

Resistant to yellow rust only: DBW182, DDW32, HD3171, HPBW07, HS596, HUW688, HUW695, Macs3972, PBW709, UP2883, VL3002

Resistant to brown rust only: DBW147, HPBW08, MACS3949, MACS4024, TL302, TL303, WB5

a. Rust resistance genes in AVT lines

To know the genetic diversity in Advance Varietal Trial material, rust resistance genes were characterized using host-pathogen interaction data and applying gene matching technique. Mostly rust resistance genes were inferred in those wheat lines where differential response to rust pathotypes were observed. However, morphological markers, genetic linkage and characteristic infection types were also used to reach at a conclusion.

***Yr* genes**

AVT II

Five *Yr* genes (*Yr*2, A, 9, 18 and 27) to yellow rust of wheat were characterized in 47 lines of AVT II. Among these *Yr*2 was inferred in more than70 % lines followed by *Yr*9 gene which was characterized in about 30% lines. Other resistance genes were postulated in few lines only (Table 6).

Table 3: Pathotype distribution of yellow rust (*Puccinia striiformis*) in India and neighboring country during 2014-15

S. No.	States/ Countries	Rust samples		Pathotypes identified										Barley Pathotypes Identified	
		Received	Analyzed	46S119	78S84	T(47S103)	P (46S103)	110S119*	238S119*	46S117*	110S84*	7S0	CI (14S64)	M (1S0)	57 (0S0)
1.	Tamil Nadu	13	05	05#	-	-	-	-	-	-	-	-	-	-	-
2.	Punjab	101	39	27	02	-	-	05	-	04	-	01	-	-	-
3.	Haryana	32	10	06	-	-	-	02	-	-	02	-	-	-	-
4.	Rajasthan	38	14	10	03	-	-	-	-	-	-	-	-	-	01
5.	Uttarakhand	104	43	28	01	-	01	10	-	-	-	-	-	02	01
6.	Himachal Pradesh	262	147	113	04	01	01	12	08	03	01	01	-	03	-
7.	Jammu & Kashmir	91	51	21	01	01	01	16	05	04	01	-	01	-	-
Other countries															
1	Nepal	77	30	27	-	-	-	-	-	-	-	-	-	02	01
2	Bhutan	07	02	02	-	-	-	-	-	-	-	-	-	-	-
Total		**725**	**341**	**239**	**11**	**02**	**03**	**45**	**13**	**11**	**04**	**02**	**01**	**07**	**03**

*** New pathotypes, # confirmation is required**

Table 4: Pathotype distribution of brown rust (*P. triticina*) in India and neighboring country during 2014-15

S. No.	State	Rust samples		Pathotypes identified																						
		Received	Analyzed	10 (13R19)	12-2 (1R5)	12-3(49R37)	12-4 (69R13)	12-5 (29R45)	12-7 (93R45)	12 A (5R13)	77-1 (109R63)	77-2(109R31-1)	77-5(121R63-1)	77-6(121R55-1)	77-9(121R60-1)	77-10(377R60-1)	77-11(125R28)	77-12(121R52-1)	77A(109R31)	104-2(21R55)	104-3(21R63)	104-4(93R57)	104B(29R23)	162(93R7)	162-2(93R39)	162-3(29R7)	162A(93R15)	162-1(93R47)
1	Tamil Nadu	72	74			1							30	1	33	2		5		1	1							
2	Maharashtra	38	37										7		29	1*												
3	Karnataka	120	109								1		26		56	1*				21	1				2	1		
4	Gujarat	05	05																	5								
5	Madhya Pradesh	31	30		1			3					13		11					2								
6	Punjab	19	18										1		15					2								
7	Haryana	09	06										1		1					4								
8	Uttarakhand	32	32					1			1		8		2					9	4	5		1			1	
9	Himachal Pradesh	16	18					1	1				6				1			5	2	1						1
10	Jammu & Kashmir	01	-																									
	Other Countries																											
1	Nepal	48	42				5				2	1	25						1	5	1	1	1					
2	Bangladesh	39	11	1						2			4							1	2	1						
3	Bhutan	08	04										3							1								
Total		**438**	**386**	**1**	**1**	**1**	**5**	**5**	**1**	**2**	**4**	**1**	**124**	**1**	**147**	**4**	**1**	**5**	**1**	**56**	**11**	**8**	**1**	**1**	**2**	**1**	**1**	**1**

* Confirmation is required

10(13R19)=SGHLL, 12-2 (1R5)=FGTTL, 12-3(49R37)=FHTRL, 12-4(69R13)=FGTRM, 12-5(29R45)=FHTPM, 12-7(93R45)=FHTTL, 12A(5R13)=FGTTL,77-1(109R63)=THTTB,77-2(109R31-1)=TGTTL, 77-5(121R63-1)=THTTM,77-6(121R55-1)=THTTL, 77-9(121R60-1)=MHTKP,77-10(377R60-1)=MHTKQ,77-11(125R28)=MGTTL,77-12(121R52-1=MGTNL,77A(109R31)=TGTTB, 104-2(21R55)=PHTTL,104-3(21R63)=PHTTL,104-4(93R57)=NHKTL, 104B(29R23)=MGTDL,162(93R7)=KGTSC,162-1(93R47)=KHTTM, 162-2(93R39)=KHTTL, 162-3(29R7)=KGTPL, 162A(93R15)=KGTSB; Figures in parentheses are the Indian binomial names and those in letters are North American equivalents based on Kolmer J A, Ordonez, M E, Manisterski J and Anikster Y. 2011. *Phytopathology* 101:870-877.

Table 5: Pathotype distribution of black rust of wheat (*Puccinia graminis* f. sp. *tritici*) in India and neighboring country during 2014-15

S. No.	States/ Countries	Rust samples		Pathotypes identified							
		Received	Analyzed	11 (79G31)	40A (62G29)	40-3 (127G29)	21 (9G5)	21-1 (24G5)	21A-2 (75G5)	34-1 (10G13)	122 (7G11)
1	Tamil Nadu	34	14	04	09	-	-	-	-	-	01
3	Maharashtra	07	07	07	-	-	-	-	-	-	-
4	Madhya Pradesh	07	06	02	-	03	-	01	-	-	-
5	Gujarat	24	26	24	02	-	-	-	-	-	-
2	Uttarakhand	28	13	-	-	-	01	08	04	-	-
6	Jammu and Kashmir	06	06	-	-	-	-	-	-	06	-
Total		**106**	**72**	**37**	**11**	**03**	**01**	**09**	**04**	**06**	**01**

North American equivalents of pathotypes:11(79G31)=RRTSF, 21(9G5)=CHMSC, 21-1(24G5)=CKMSC, 21A-1(75G5)=CHTSC, 34-1(10G13)=MHGSF, 40-3(127G29)=PTTSF, 40A(62G29)=PTHSC, 122(7G11)=RRHSC based on Jin Y , Szabo L J , Pretorius Z A , Singh R P , Ward R and Fetch T Jr .2008 . *Plant Dis.* 92: 923-6.

AVT I

Three *Yr* genes (*Yr*2, A and 9) were observed in 67 lines. *Yr*2 was postulated in 40 lines followed by *Yr*9 in 19 lines and *Yr*A in 7 lines only (Table 7).

***Sr* genes**

AVT II

Eleven *Sr* genes (*Sr*2, 5, 8a, 7b, 9b, 9e, 11, 13, 24, 25 and 31) were characterized in 65 lines. *Sr*2 based on characteristic mottling was observed in 56 lines followed by *Sr*11 in 23 lines and *Sr*31 based on its linkage to *Lr*26/*Yr*9 in 13 lines. The resistance of most of the durums was based on *Sr*7b, 9e and *Sr*11. Other *Sr* genes were inferred only in few lines (Table 8).

AVT I

Fourteen *Sr* genes (*Sr*2, 5, 7b, 8a, 9b, 9e, 11, 12, 13, 15, 24, 25, 30 and 31) were inferred in 99 lines. *Sr*2, known adult plant resistance gene to stem rust was observed in 64 lines followed by *Sr*11 in 37, *Sr*7b in 34 and *Sr*31 in 19 lines. *Sr*9e was characterized in 7, *Sr*13 in 6 lines whereas remaining eight *Sr* genes were postulated in few lines only (Table 9).

***Lr* genes**

AVT II

Nine *Lr* genes (*Lr*1, 10, 13, 14a, 19, 23, 24, 26, 34) were identified in 60 lines where differential host pathogen interactions were observed. Gene *Lr*13 was postulated in 22 lines followed by *Lr*23 in 21, *Lr*26 in 13 and *Lr*10 in 11 lines. *Lr*1, *Lr*34 and *Lr*24 were found to confer brown rust resistance in 8, 6 and 4 lines, respectively. In addition *Lr*14a and *Lr*19 were characterized in one line each (Table 10).

AVT I

Nine *Lr* genes viz. *Lr*1, 2a, 10, 13, 19, 20, 23, 24 and 26 were characterized in 87 lines. Among these *Lr*13 was most common and was observed in 49 lines. This gene is known widely for conferring resistance to brown rust at high temperatures. *Lr*23 was characterized in 30 lines followed by *Lr*10 in 24, *Lr*26 in 19 and *Lr*1 in 16 lines. Other resistance genes namely *Lr*2a, *Lr*19 and *Lr*24 were observed in 3, 1 and 1 lines, respectively (Table 11). These had been further decrease in the proportion of *Lr*26 in AVT I accessions in comparison to the previous years.

Table 6: *Yr* genes in AVT II[nd] material during 2014-15

Yr Genes	No. of Lines	Details of Lines
2+	30	HD2864(C), HD2932+*Lr*19/*Sr*25, HD2967(C), HD2985(C), HD3086(C), HD4728(D), HI4730, HD888(C), HI1544(C), HI1563(C), HI8498(D) (C), HI8737 (D)(I)(C), HPW349(C), HS542(C), HUW234(C), K0307(C), K8027(C), MACS6478(C), MP3336(C), MP4010(C), NIAW2030, PBW343, PBW644(C), PDW314(C), RAJ4083, UAS347(I)(C), UAS446(D)(I)(C), WH1080(C), WH1105(C), WH1129(C)
2+18+	1	NI5439
9+	8	DBW93(I) (C), HPW251(C), HS507(C), NIAW1415(C), PBW343(C), WH542 (C), WH1021(C), WH1142(C)
9+18+	4	HS375 (C), VL804(C), VL829(C), VL907(C)
18+	1	C306(C)
9+27+	1	MACS6222(C)
A+	2	HS562, VL892(C)
Total	**47**	

Table 7: *Yr* genes in AVT I[st] material during 2014-15

Yr Genes	No. of Lines	Details of Lines
2+	40	DBW148, DBW150, DBW181, DBW184, DBW185, HD3159, HD3165, HD3174, HD3209, HI1604, HI1605, HI8765(D), HPBW05, HPW393, HPW413, HPW421, HPW422, HS583, HS601, HUW711, HUW712, JWS712, K1312, K1315, KB2012-13, KRL350, MACS3949, MACS5043, MACS6507, PBW707, PBW718, TL3001, TL3004, TL3005, UAS360, UAS453(D), WB1, WB2, WH1179, WH1309
9+	9	DWR-NIL-01, DWR-NIL-02, HPBW01, HPBW02, TL3002, TL3003, UP2918, VL4001, WB5
9+A+	10	HS580, HS599, K1317, PBW719, UP2917, UAS361, VL1005, VL1007, VL3007, VL3008
A+	8	DBW147, HD3164 (D), HS598, HS600, K1313, K1314, PBW716, VL3009
Total	**67**	

Table 8: *Sr* genes in AVT IInd material during 2014-15

***Sr* Genes**	**No. of Lines**	**Details of Lines**
31+5+2+	2	HS375 (C), VL804 (C)
31+2+	8	DBW93(I) (C), HPW251 (C), MACS6222 (C), NIAW1415 (C), PBW343 (C), VL907 (C), WH1021 (C), WH1142 (C)
31+	3	HS507 (C), WH542 (C),VL829(C)
24+2+	4	HD2888 (C), HI1544 (C), MP4010 (C), NAW2030
25+2+	1	HD2932+*Lr*19/*Sr*25
13+2+	1	DBW90 (C)
5+8a+9b+11+2+	1	HS542 (C)
8a+9b+11+2+	1	KRL19 (C)
8a+11+2+	1	HD2967 (C)
8a+9b+	1	HS562
9e+2+	5	HI8737 (D) (C), PDW233 (C), PDW291 (C), PDW314 (C), WH1080 (C)
11+2+	15	DBW88 (C), DDK1029 (C), GW322 (C), HD3059 (C), HD4727(C), HI4730, HI8498 (D) (C), HW1098 (C), K8027 (C), MACS392 (C), PBW644 (C), RAJ4083 (C), UAS428 (D)(C), UAS446 (D) (I) (C), WH1105 (C)
11+7b+2+	2	MP1277, UAS347 (I) (C)
9b+11+	1	HUW234 (C)
11+	2	MPO1215 (D) (C), NI5439 (C)
9b+2+	1	HS490 (C)
7b+2+	3	AKDW2997 (D), HD3086 (C), WH1124 (C)
7b+	2	HD2985 (C), KRL210 (C)
2+	11	DBW14 (C), HI1563 (C), HPW349 (C), K0307 (C), MP3336 (C), PBW621-50 (C), PBW723, TL2942 (C), TL2969 (C), VL892 (C), WH1164
Total	**65**	

Table 9: *Sr* genes in AVT Ist material during 2014-15

Sr Genes	No. of Lines	Details of Lines
31+5+	1	HS580
31+2+	14	HPBW01, HPBW02, HS599, K1317, TL3002, TL3003, UAS361, UP2917, UP2918, VL1005, VL1007, VL3007, VL4001, WB5
31+	4	DWR-NIL-01, DWR-NIL-02, PBW719, VL3008
24+2+	1	JWS712
25+11+2+	1	HD3209
30+5+2+	1	K1313
30+2+	2	DBW147, HS598
30+	2	UAS360, VL3009
11+	6	HI1604, HPW393, HPW394, HPW422, HS596, UP2883
2+	2	TL3001, VL3002
11+2+	6	DDW31, GW463, HI8759 (D), HS597, MACS4024, VL1006
11+12+2+	2	MACS3972 (D), MACS4020 (D)
11+13+2+	1	HUW712
13+7b+2+	1	K1315
9e+11+5+	1	PBW721
9e+11+2+	1	HPBW08
9e+5+	1	KRL351
9e+7b+2+	3	DBW181, UAS453 (D), UAS455(D)
9e+	1	PBW718
9b+11+2+	1	HS583
9b+11+	3	HI8765 (D), PBW709, PBW707
8a+11+5+	1	HPW421
8a+5+2+	1	HPBW05
8a+2+	1	DBW183
5+11+13+2+	3	DBW182, HUW695, HUW711
5+11+13+	1	HD3159
5+7b+9b+2+	1	WH1309
5+11+2+	2	KB2012, MACS6507
5+11+	3	HI1605, HUW1688, K1312
5+7b+2+	4	CG1015, DBW185, K1314, TL3005
5+7b+	1	HS601
5+2+	2	HPBW09, TL3004
7b+2+	11	DBW148, DBW150, DDW32, HD3165, HD3174, HS590 HS600, MACS3949, PBW716, WB1, WB2
7b+11+2+	2	DBW184, KRL350
7b+15+2+	1	MACS5041
7b+11+	3	GW1315 (D), HPBW07, MACS5043
7b+	7	DDK1048, DDK1049, HD3164, HD3171, HPW413, Macs3970(D), WH1179
Total	**99**	

Table 10: *Lr* genes in AVT IInd material during 2014-15

***Lr* gene/s**	**No. of Lines**	**Details of Lines**
26+23+34+	1	WH542 (C)
26+23+1+	1	DBW93 (I) (C)
26+34+1+	1	HS375 (C)
26+34+	2	VL804 (C), VL829(C)
26+23+	2	HPW251 (C), WH1142 (C)
26+1+	3	HS507 (C), MACS 6222 (C), WH1021 (C)
26+	3	NIAW1415 (C), PBW343 (C), VL907 (C)
24+	4	HD2888 (C), HI1544 (C), MP4010 (C), NIAW2030
23+1+	2	K0307(C), MACS6478(C)
23+	15	DBW14(C), HD2958(C), HD2967(C), HD3043(C), HI8498 (D) (C), HI8737 (D) (C), HS490(C), HS562, MPO1215(D) (C), PDW233 (C), PDW291 (C), PDW314 (C), RAJ4083(C), TL2969(C), UAS428(D) (C)
19+	1	HD2932+Lr19/Sr25
13+10+3+	2	DBW90(C), HD3086(C)
13+10+	9	HPW349(C), KRL210(C), HS542(C), PBW621-50(C), TL2942(C). UAS347(I)(C), VL892(C), WH1124(C), WH1164
13+1+	1	PBW644(C)
13+	10	DDK1029(C), GW322(C), HD2932(C), HD3059*, K8027(C), KRL19(C), MP1277, MP3336(C), WH1080(C), WH1105(C)
14a+	1	HUW234(C)
34+	2	C306, NI5439
Total	**60**	

*Different seed lot than the previous year.

Table 11: *Lr* genes in AVT Ist material during 2014-15

Lr gene/s	No. of Lines	Details of Lines
26+23+1+	3	UAS361, UP2918, VL1005
26+23+10+	2	HPBW01, HPBW02
26+23+	2	DWR NIL01, PBW719
26+10+	3	HS599, UP2917, VL4001
26+1+	6	HS580, K1317, TL3002, TL3003, VL3007,WB5
26+	3	DWRNIL02, VL1007, VL3008
24+	1	JWS712
23+13+10+	3	PBW709, PBW716, VL1006
23+13+1+	1	HS600
23+13+	2	CG1015, DDW31
23+10+1+	2	DBW150,HPW393
23+10+	4	DBW148, HPW413, HUW695, KB2012-13
23+1+	4	GW463, HI1604, K1315, KRL350
23+	7	DDW32, HD8765 (D), HI8759(D), HPW421, HPW422, HS596, HUW711
19+	1	HD3209
13+10+	10	DBW182, DBW185, HD3171, HPW394,HS583, K1312, KRL351, TL3001, VL3002, WH1309
13+2a+	3	HS598, UAS360, VL3009
13+	30	DBW181, DBW183, GW1315(D), HD3159, HD3164, HD3165, HD3174, HI1605, HPBW05, HPBW07, HS590, HS597, HS601, HUW712, K1313, K1314, MACS3970 (D), MACS3972 (D) , MACS6507 , PBW707, PBW718, PBW721, TL3004, TL3005, UAS453 (D),UAS455(D), UP2883, WH1179, WB2, WB9
Total	**87**	

6. Seedling rust resistance in barley against barley pathotypes

Two hundred thirty three lines of EBDSN (97) and NBDSN (136) were evaluated at seedling stage using three pathotypes of barley yellow rust viz. (0S0)57, 1S0 (M), 5S0 (Q) , mixture of *Puccinia striiformis* f. sp. *hordei* (Yellow/stripe rust), five pathotypes 79G31(11), 62G29(40A) and 75G5 (21A-2), 37G19 (117-6), 7G43 (295) of *P. graminis* f. sp. *tritici* (Black/stem rust) and H4 isolate as well as mixture of five isolates of *P. hordei* (Brown/leaf rust) under controlled conditions. One week old seedlings were inoculated and incubated in saturated humidity chambers for 48 hours. Subsequently these plants were transferred on to the greenhouse benches where sufficient day light (more than 10,000 Lux) and temperature of 16±2^{o}C (for yellow rust), 22±2^{o}C (for brown rust) 24±2^{0}C (for black rust) and relative humidity of 40-60% were maintained. Observations recorded are summarized below.

Rust resistant lines in EBDSN

Three lines viz. BCU7719, BH972 and BH983 were resistant to all the rusts. In addition 6 lines were resistant to black & brown, 2 to brown & yellow and 1 line to yellow & black rusts. Seven lines were resistant to yellow rust only (**Table 12**).

Table 12: Rust resistant in EBDSN entries

Resistant to rusts	No. of Lines	Lines
All	03	BCU7719, BH972, BH983
Black and Brown	06	BCU7598, BCU7621, BCU7623, BCU7643, BCU7732, BCU7746
Brown and Yellow	02	HBL713, HUB237
Yellow and Black	01	BH981
Yellow	07	BCU7615, BCU7616, DWRB127, KB1351, KB1367, UPB1040, UPB1042

Rust resistant lines in NBDSN

Nine lines (RD2035, RD2550, RD2552, RD2849, RD2900, RD2904, RD2909, RD2913, and RD2915) were resistant to all the three rusts of barley. Five lines were resistant to black & brown rusts, 7 to brown & yellow rusts and 12 to yellow & black rusts. Eighteen lines were resistant only to yellow rust of barley (**Table 13**).

Table 13: Rust resistance in NBDSN entries

Resistant to rusts	No. of Lines	Lines
All	09	RD2035, RD2550, RD2552, RD2849, RD2900, RD2904, RD2909, RD2913, RD2915
Black and Brown	05	BH994, BH995, DWRB141, HUB242, RD2919
Brown and Yellow	07	NDB1607, NDB1618, RD2550, RD2786, RD2901, RD2905, RD2907
Yellow and Black	12	BH993, BH999, DWRB132, HUB113, HUB243, RD2035, RD2552, RD2891, RD2903, RD2908, RD2914, VPB1046
Yellow	18	BH1000, BH902, BH996, DWRB137, DWRB143, DWRB64, HUB240, HUB241, HUB242, HUB244, HUB245, JB301, JB303, KB1318, PL887, RD2715, RD2899, RD2910

Table 14: Details of the material evaluated for rust resistance during 2014-2015

Sr. No.	Details of Lines	No. of Lines	Pathotypes		
			Black rust	Brown rust	Yellow rust
1.	ICAR-NBPGR	40	40A and Mix	77-5 and 104-2	46S119 and 78S84
2.	Vijay Rana, RWRC, Malan, HP	82	-	12-2, 77-2, 77-5 and 104-2	46S119 and 78S84
3.	BARC, Mumbai	14	Multiple	12-2, 77-2, 77-5 and 104-2	-
4.	JP Jaiswal, GBPUAT, Pantnagar	166	-	12-2, 77-5 and 104-2	46S119 and 78S84
5.	SR Verma, HAU, Hisar	55	11, 40A, 40-3 and 117-6	12-2, 77-2, 77-5 and 104-2	46S119, 78S84, K and P
6.	Rashmi Agarwal, ICAR-IARI, New Delhi	33	34-1	77-5 and 104-2	-
7.	AP Agrawal, IGKV, Raipur	50	11, 21A-2, 40A and 117-6	-	-
8.	S.K.Singh, ICAR-IIWBR, Karnal	252	Multiple	Multiple	Multiple
9.	AVT I & II	173	Multiple	Multiple	Multiple
10.	EBDSN	97	Selected	Selected	Selected
11.	NBDSN	136	Selected	Selected	Selected
12.	VK Vikas,ICAR-IARI, Wellington, TN	12	Multiple	Multiple	Multiple
13.	V Tiwari, ICAR-IIWBR, Karnal	76	40A, 40-3, 117-6	77-2, 77-5, 104-2, 104-4, mixture	Multiple
14.	Madhu Patial, ICAR-IARI, Shimla	105	-	-	Barley pts. M, Q
15.	Raghu BR	125	-	77-5, 104-2	46S119, 78S84 and P
16.	Released cultivars	50	-	-	Multiple
17.	*Yr* -lines	62	-	-	Multiple
18.	Barley lines	54	-	Selected	Barley pts. G, M, Q, 57
19.	PC Sharma, CSSRI, Karnal	80	-	77-2, 77-5, 104-2	46S119, 78S84 and P
20.	PAU, Ludhiana	132	-	-	46S119, 78S84
21.	Satvinder Kaur	232	-	77-5, 104-2	46S119, 78S84 and K
22.	BHU, Varanasi	54	34-1, 40-3, 40A, 117-6	12-2, 12-5, 77-2, 77-5, 77-9, 104-2	46S119, 78S84
23.	Kamini Kaushal, ICAR-IARI, Indore	144	-	Multiple	-
24.	Vaibhav Singh	05	Multiple	Multiple	Multiple
25.	Rudra Naik	67	Multiple	Multiple	-
26.	ICAR-IARI, Indore	08	15-1, 40A, 40-3, 117-3, 117-5, 117-6	-	-
Total		**2310**			

7. Adult Plant Resistance (APR) in advance wheat material to rusts

To find out the race specific APR in advance wheat material, 173 lines of AVT II and I were evaluated at adult plant stage under optimum growth conditions against the pts. 77-5, 104-2 (Brown rust), 46S119, 78S84 (Yellow rust), 40A, 117-6 (Black rust) separately in different polyhouses. Lines which were susceptible at seedling stage but showing resistance at adult plant stage, assumed possessing APR. In AVT II wheat material, 30 and 15 lines

showed APR for both pathotypes of yellow and brown rust, respectively (Table 15). APR to black rust was not observed in these lines except lines AKDW2997 (D) and UAS428 which possessed APR to pt 117-6. In AVT I, eighteen lines revealed APR to both pathotypes of brown rust whereas only one line (DDW32) having APR to both pathotypes of black rust (Table16).

8. Molecular studies

Validation the presence of rust resistance genes

Microsatellite markers (SSR) were applied to validate the presence of rust resistance genes and the plants which were confirmed to carry resistance genes were selected and harvested. The following known SSR markers were used for selection and gene pyramiding (Table 17). Variability in the new pathotypes of yellow rust i.e. 6S0 and 7S0 was observed by applying microsatellite markers.

9. Genetic studies and development of rust resistant genetic stocks

a. Selection in spring winter segregating stock nursery (SWSSN) 2014-15

The spring winter wheat F_2 segregating stock nursery comprising 45 crosses were screened against most virulent pathotypes of brown, yellow and black rusts of wheat at seedling stage. Using all the 45 F_2 populations, 162 rows of one meter were transplanted in field after removing susceptible progenies. Total 150 plants were selected from 43 F_2 populations and F_3 seed was harvested. The selections were made for resistance to rust, earliness in maturity, plant height, number of tillers/plant, spike length, yield/plant and seed colour.

Table 15: Adult Plant Resistance (APR) in AVT II

APR to	Pathotypes	No of Lines	Lines
Brown rust	77-5	**12**	DBW14(C), DBW88(C), HD2967(C), HD3059(C), HPW251(C), HS375(C), MMBL283, MP4010(C), PBW314(C), VL804(C), WH1021(C), WH1080(C).
	104-2	**17**	C306(C), DBW93(C), DDK1029(C), HD2985(C), HI1563(C), HS490(C), HUW234(C), Kharchia65(C), KRL210(C), MACS392(C), MP1277, MP3336(C), UAS347(C) (I), VL892(C), WH542(C), WH1142(C), WH1164.
	77-5 and 104-2	**15**	DBW90(C), HD3043(C), HD3086(C), HI8737(D) (C), HPW349(C), HS562, HW1098(C), PBW233(C), PBW343(C), PBW644(C), RAJ4083(C), TL2942(C), TL2969(C), VL829, WH1124(C).
Yellow rust	46S119	**07**	DBW88(C), DBW90(C), HS562, K8027(C), MP3336(C), VL892(C), WH1021(C).
	78S84	**06**	HI8737(C), HUW234(C), PBW314(C), UAS446(D)(I)(C), VL829, WH1164.
	46S119 and 78S84	**30**	DBW14(C), DPW621-50(C), HD2888(C), HD2967(C), HD3086(C), HD4727(C), HI4730, HI1563(C), HI4730(C), HPW251(C), HPW349(C), HS375(C), HS507(C), HS542(C), K0307(C), MACS6478(C), MMBL283, PBW233(C), PBW291(C), PBW644(C), RAJ4083(C), TL2942(C), TL2969(C), UAS428(C), VL804(C), VL907(C), WH1080(C), WH1105(C), WH1124(C), WH1142(C).
Black rust	40A	**-**	-
	117-6	**02**	AKDW2997(D), UAS428 (D) (C).
	40A and 117-6	**-**	-

Table 16: Adult Plant Resistance (APR) in AVT I

APR to	Pathotypes	No of Lines	Lines
Brown rust	77-5	**15**	CG1015, DDW31, DDW32, GW1315(D), GW463, HI1604, HPBW05, HUW712, K1315, KB2012, KRL351, PBW719, TL3005, VL1006, WH1309.
	104-2	**22**	DBW148, DBW183, DBW185, DDK1048, DDK1049, DWR-NIL-02, HD3159, HD3171, HPBW01, HPBW07, HPW394, HPW413, HPW421, HS583, HS601, K1314, MACS5041, PBW707, TL3001, UAS360, VL3009, WH1179.
	77-5 and 104-2	**18**	DBW181, DBW182, DBW184, HD3165, HD3174, HI1605, HI8759 (D), HPW393, HPW422, HS597, HS598, MACS3972(D), MACS6507, PBW718, TL3004, UAS455(D), UP2883, VL1007.
Yellow rust	46S119	**15**	HPBW01, HS580, HS599, K1312, K1314, K1315, K1317, MACS6507, PBW147, PBW719, TL3005, UAS453(D), UP2918, VL3008, VL3009.
	78S84	**07**	HPW393, WH1179, PBW721, TL3002, TL3003, TL3004, HPBW08
	46S119 and 78S84	**20**	DBW181, DBW184, DBW185, DDW31, HI1605, HI8765(D), HPBW02, HPBW05, HPW413, HPW421, HUW711, HUW712, KRL350, MACS3970(D), MACS4020(D), UAS455(D), VL4001, WB1, WB2, WB5.
Black rust	40A	**12**	CG1015, HD3171, HPW393, HPW413, HS583, HUW688, K1312, K1315, KRL351, UAS360, UAS455(D), WH1309.
	117-6	**11**	DBW148, DDW31, GW1315, HD3165, HI8765(D), HS597, MACS3970(D), MACS4020(D), MACS4024, MACS5041, MACS5043.
	40A and 117-6	**01**	DDW32

Table 17: List of SSR markers were used for selection and gene pyramiding

Gene	marker	Marker sequence	Population/ cultivar	Usefulness
*Yr*15/*Yr*24	GWM11	F5` GGATAGTCAGACAATTCTTGT 3` R5` GTGAATTGTGTCTTGTATGCTTCC 3`	F2 HSB-4/VL907	Very good, not for Yr24
*Yr*15	BARC8	5' CGGGAATCATGCATAGGAAAACAGAA 3' R5' GCGGGGGCGAAACATACACATAAAAACA 3'	F2 HSB-4/VL907	Good
*Yr*9/*Lr*26/*Sr*34	IAG95-STS	F5' CTCTGTGGATAGTTACTTGATCGA 3' R5' CCTAGAACATGCATGGCTGTTACA 3'	F2 HSB-4/VL907, PBW343	Very ggod
*Yr*18/*Lr*34	csLV34	F5` GTTGGTTAAGACTGGTGATGG3` R5` TGCTTGCTATTGCTGAATAGT3`	AO-88 NIAW-34,	Very good
*Lr*35/*Sr*39	Sr39#22	F5` AGAGAAGATAAGCAGTAAACATG 3` R5` TGCTGTCATGAGAGGAACTCTG 3`	F5 Lok-1/Sr39	Good
*Lr*35/*Sr*39	Sr39#50	F5` CCAATGAGGAGATCAAAACAACC 3` R5` TAGCAAGGACCAAGCAATCTTG 3`	F5 Lok-1/Sr39	Good
*Sr*26	Sr26#43	F5' AATCGTCCACAT TGGCTTCT 3' R5' CGCAACAAAATCATGCACTA 3'	F4 NI5439/Kite, F4 Raj3765/Kite, Lok-1/kite	Good
*Sr*32	csSr32#1	F5` GGTTTGGTGGCAACTCAGGT 3' R5`CATAAGCCAAAGAGGCACCA 3'	Lok-45/Sr32, Lok-1/ Sr3	Good
*Sr*43	CFA2040	F5` TCAAATGATTTCAGGTAACCACTA 3' R5` TTCCTGATCCCACCAAACAT 3'	F2Sr43/VL892	Very good
*Yr*29/Lr46	WMC44-1b	F5' GGTCTTCTGGGCTTTGATCCTG 3' R5' TGTTGCTAGGGACCCGTAGTGG 3'	Pavon76, Lal Bahadur,	Good
*Yr*46/*Lr*67/*Sr*55	CFD23	F5` TAGCAGTAGCAGCAGCAGGA 3` R5` GCAAGGAAGAGTGTTCAGCC 3`	RL6077, Agra Local	Poor

The following four crosses with pedigree were found more useful for selection.

- KAROUS-4-1/7/NE COMP1/5/BEZ//TOB/8156/4/ON/3/TH*6/KF//LEE*6/K/6/ TAST/SPRW…./RUBY(Yr27)/VL892 (**VHW6211**)
- MARVDASH/SO/SSONS//ALVAND/VL892 (**VHW6218**)
- RL6043/4*NAC//PASTOR/3/BABAX/VL892 (**VHW6219**)
- ZANDER33/VL907//QLD40 (**VHW6276**)

Selected progenies from SWSSN 2012-13 and SWSSN 2013-14 were also planted after screening them against most virulent pathotypes of the three wheat rusts and 33 F_5 and 124 F_4 plant progenies were harvested after selection for yield traits.

b. Development of rust resistant genetic stocks

Three advance line genetic stocks were characterized for stem rust resistance and yield components. Preliminary yield trials were conducted at Flowerdale and Tutikandi in Shimla. In these three resistant stocks viz FLW31, FLW32 and FLW33 varieties of Central Zone (CZ) and Peninsular Zone (PZ) were used to introgress *Sr43*, *Sr26* and *Sr32* genes, respectively. These resistance genes were selected for transfer as they provide complete resistance against all the virulent pathotype of black found in Indian subcontinent as well as

considerable resistance against Ug99 race and its variants. The stocks were also evaluated in Kenya during 2013-14 and were found to carry resistance against Ug99 pathogen of stem rust. For registration with NBPGR and to make them available for use by wheat breeders, seed of these genetic stocks has been multiplied in the 2014-15. Table 18 shows the pedigree and morpho-agronomic characters of the three genetic stocks.

Table 18: Characteristics of three Ug99 resistant genetic stocks

Genetic stock	Pedigree	Rust resistance genes present	Plant Height (cm)	Days to maturity	1000 grain weight	Yield/M row (g)	Grain Colour
FLW31	HI1500/*Sr43*	*Lr24, Sr24, Sr43*	105	155	41.6	124	Amber
FLW32	Raj3765/Eagle (*Sr26*)	*Yr2ks, Lr10, Lr13, Sr2, Sr26*	99	152	42.1	131 g	Amber
FLW33	HI1500/S*r32*	*Lr24, Sr24, Sr32*	94.3	145	41.4	122	Amber

Doubled haploid production using wheat F_1's as female parent and maize as pollinator was attempted. Karyopsis formation was recorded in more than 80% florets while haploid embryo recovery was less than 5%. Pollination using *Imperata cylindrica* (Blade grass) could not be attempted because of the non synchronisation due to very late flowering in the blade grass. Culture media was standardized for growing rescued haploid embryos.

c. Gene pyramiding and genetic analysis for rust resistance:

Fifteen F_1 crosses and five backcrosses were attempted during wheat season 2014-15. Thirty two F_1 and five F_2 crosses were tested and advanced for genetic analysis. Six F_2s and Four BC_1F_2 crosses were tested for resistance to rusts at seedling stage and resistant progenies were transplanted for gene pyramiding.

The rust resistance genes which are being transferred/incorporated in different backgrounds are *Yr15*, *Yr 24*, *YrUN*, *Sr26*, *Sr32*, *Sr39* and *Sr43*. Sixteen segregating populations viz. HSB-4(2398 Yr15+Yr24)/VL907, HSB-4 (Yr15+Yr24)/ HS507 (F_3), DPW621-50/Yr24KS (F_3), HI1500/ *Sr*43 (F_7), NI5439/Eagle *Sr26* (F_7), Lok-1/ *Sr*39 (F_5), Lok-1/*Sr*32 (F_4), Lok-45/Kite (F_4), Lok-45/*Sr*32 (F_4), HI1500/*Sr*32 (F_7), Raj 3765/ Eagle *Sr26* (BC_2F_7), *Yr*2/Kalyansona (F_4), Lok-1/ Kite *Sr26* (F_4), HI1077/Kite (F_4), Raj 3765/Kite (F_4) and NI5439/Kite (F_4) were evaluated for rust resistance against the pathotypes of rusts

and plant characters. Selected plants were used for generation advancement to pyramid genes of rust resistance.

Five populations were advanced through single head descent to generate recombinant inbred line (RILs) for mapping candidate gene for rust resistance. The six populations are FLWH/Lok-1 (brown rust), NIAW-34/LWH (APR brown rust), AL/NI5439 (black rust), AL/HI1077 (brown rust), AL/HD2922 (brown rust) and Local red/ MACS2971 (brown rust). Three F_3 populations were sown at Dalang Maidan summer nursery for generation advancement.

10. Maintenance and supply of nucleus inoculum of wheat and barley rusts

A collection of 127 pathotypes of different rust pathogens of wheat, barley, oat and linseed was maintained in live culture as well as cryo-preserved. To enable researchers conduct research on wheat and barley rusts, nucleus/bulk inocula of different rusts of wheat and barley was supplied to 20 centers/scientists working under public and private sector across India (Table 19) for the smooth conduct of rust research during January- June, 2015.

11. Wheat Disease Monitoring Nursery and SAARC Wheat Disease Monitoring Nursery

The 47th wheat disease monitoring nursery (earlier trap plot nursery) was planted at 43 locations covering all the major wheat growing areas in the country, especially those situated near the bordering areas to the neighboring countries. WDMN has helped in knowing the seasonal progress of wheat diseases in different strategic locations in wheat growing zones. Wheat and barley rust samples collected from WDMN gives an overview of area wise distribution and load of rust pathotypes. There were 20/ or 21 entries in the nursery during 2014-15. Of these, first 15 entries were common to all zones, rest of the five/six (northern hills and high altitude zone) entries were zone specific varieties.

Under the umbrella of Regional Station, ICAR-IIWBR, Shimla and CIMMYT, Nepal, SAARC wheat disease monitoring nursery is being conducted in SAARC countries viz. Nepal, Bangladesh, Bhutan, Pakistan, Afghanistan and India with the objectives similar to the wheat disease monitoring nursery (WDMN) in India. During 2014-15, SAARC wheat disease monitoring nursery was planted at 27 locations across the six SAARC countries.

Table 19. Details of wheat and barley rusts inocula supplied during Jan-June, 2015

S. No.	Name	Place	Rusts /pathotypes
1.	BK Honrao	Pune, Maharashtra	Black (40A, 117-6)
2.	CN Mishra	IIWBR, Karnal, Haryana	Brown (pt. 77-5 & mix), Yellow (pt. 78S84)
3.	Deepshikha	GBPUAT, Pantnagar, UK	Yellow mix (13, K, L, P, 46S119, 78S84), Brown mix (pts. 12-2, 77-2, 77-5, 104-2)
4.	DP Walia	Tutikandi, Shimla, HP	Brown (pt. 77-5), Yellow (pt. 78S84, 46S119)
5.	Daisy Basandrai	Dhaulakuan, HP	Yellow mix
6.	Dhanvir Singh	Dhaulakuan, HP	Barley yellow mix
7.	J Kumar	IARI, Shimla, HP	Brown (pt.77-5), Yellow (pts. 46S119, 78S84)
8.	JP Jaiswal	GBPUAT, Pantnagar, UK	Brown mix, Yellow mix
9.	KK Mishra	Powarkheda, MP	Black mix, Brown mix
10.	Madhu Patial	Tutikandi, Shimla, HP	Yellow (pts. 46S119, 78S84), Barley yellow (pt. M)
11.	Neelu Jain	IARI, New Delhi	Brown (pt. 77-5)
12.	PV Patil	Dharwad, Karnataka	Black mix
13.	Rajendra Singh	CCSHAU, Hisar, Haryana	Yellow mix, Brown mix
14.	SK Jain	VPKAS, Almora, Uttarakhand	Brown mix
15.	SP Singh	NDUAT, Faizabad, UP	Brown mix and yellow mix
16.	SS Karwasara	CCSHAU, Hisar, Haryana	Brown mix, yellow mix, Barley yellow mix and Brown mix
17.	Shailendra Jha	IARI, New Delhi	Brown (pt. 77-10)
18.	TR Sharma	NRCPB, New Delhi	Brown (pts. 77, 77-5, 106)
19.	Vaibhav Singh	IARI, New Delhi	Yellow (pt.78S84), Black (pts. 40A, 40-1, 117-6), Brown (pts. 12-2, 104-2, 104-3, 106, 107-1, 162A, 162-3)
20.	Vijay Rana	RWRC, Malan, HP	Yellow (pts. 46S119, 78S84), Brown (pts. 77-5, 104-2)

12. Visitors and News

a. Visitors

i. **Urmil Bansal,** Dept of Plant and Food Sciences, The University of Sydney, Australia, visited the station on 12-13th February, 2015. She discussed about new rust resistant gene identification and designation in wheat.

ii. **Ian King,** Professor of cereal genomics, the University of Nottingham, UK, visited the station on 20th Feb., 2015.

iii. **Sobhana Sivasankar,** Director, CGIAR Research Program on Dryland Cereals, was at station on 15th March, 2015.

iv. **Robert Park,** Director of Cereal Rust Research and **Davinder Singh,** Senior Research Fellow, Dept of Plant and Food Sciences, The University of Sydney, Australia appreciated the research activities of the station and discussed about wheat rusts epidemiology and management on 28th March, 2015.

v. A group of 25 students along with the staff member from Department of plant pathology, GBPUAT, Pantnagar, visited the station on 2nd May, 2015.

vi. **BK Das**, BARC, Mumbai was at station from 12th May to 14th, May, 2015.

vii. **SS Atwal,** head, IARI, regional station, Karnal, visited the station on 16th May, 2015.

viii. **Rory Hillocks**, Plant Pathologist and Nematologist, **Adrienne Martin,** Director of Programme development, Social and Institutional Development Specialist, Natural Resources Institute, University of Greenwich, UK, **Jonathan Robinson** and RPS Verma, principal scientist, ICAR-IIWBR (Current ICARDA) were at station on 16th June, 2015.

b. Joining

Neha Gupta joined station as a Senior Research Fellow from June, 2015 under ICAR funded project.

c. Foreign visits

i. SC Bhardwaj, Principal Scientist, Head and In Charge of the station, was invited by the organizer to deliver lecture in SAARC wheat rust training program on "Surveillance and monitoring of wheat rust in Nepal" at Kathmandu, Nepal, 21-22 March, 2015.

ii. Pramod Prasad, Scientist of this station attended SAARC wheat rust training program on "Surveillance and monitoring of wheat rust in Nepal" at Kathmandu, Nepal, 16-25 march, 2015.

Annexure I

Constitution of differential sets 0, A and B for the binomial designation of brown, black and yellow rust pathotypes

Set-0	Set-A	Set- B
Brown rust (*Puccinia triticina*)		
IWP 94	*Lr*14a	Loros (*Lr*2c)
Kharchia Mutant	*Lr*24	Webster (*Lr*2a)
Raj 3765	*Lr*18	Democrat (*Lr*3)
PBW 343	*Lr*13	Thew (*Lr*20)
UP 2338	*Lr*17	Malakoff(*Lr*1)
K 8804	*Lr*15	Benno (*Lr*26)
Raj 1555	*Lr*10	HP 1633 (*Lr*9+)
HD 2189	*Lr*19	
Agra Local	*Lr*28	
Black rust (*Puccinia graminis tritici*)		
*Sr*24	*Sr*13	Marquis (*Sr*7b+)
NI 5439	*Sr*9b	Einkorn (*Sr*21)
Sr25	*Sr*11	Kota (*Sr*28+)
DWR 195	*Sr*28	Reliance (*Sr*5+)
HD 2189	*Sr*8b	Charter (*Sr*11+)
Lok 1	*Sr*9e	Khapli (*Sr*7a,*Sr*13, *Sr*14)
HI 1077	*Sr*30	Tc*6/*Sr31*/*Lr26* (*Yr*9)
Barley Local	*Sr*37	
Agra Local		
Yellow rust (*Puccinia striiformis*)		
WH147	Chinese 166 (*Yr*1)	Hybrid 46 (*Yr*4)
Bilara	Lee (*Yr*7)	Heines VII (*Yr*2+)
WH416	Heines Kolben(*Yr*6)	Compair (*Yr*8)
HD2329	Vilmorin 23(*Yr*3)	*T.spelta album* (*Yr*5)
HD2667	Moro (*Yr*10)	Tc*6/*Lr*26 (*Yr9*)
PBW343	Strubes Dickkopf	Sonalika (*Yr*2+*)*
HS240	Suwon92 X Omar	Kalyansona *Yr*2(KS)
Anza	Riebesel47/51(*Yr*9+)	*Yr*24
A-9-30-1		

Binomial designations are based on the binomial values arrived at on Set A and B whereas - indicates the number of susceptible line in O set. Some of the genes show temperature sensitivity like those on locus *Lr*2, *Lr*10, *Lr*17, *Lr*18 ; *Sr*13 etc.