मेहतान्सिस

Mehtaensis

प्रो. के.सी. मेहता के नाम पर जारी क्षेत्रीय केन्द्र के शोध का छ:माही न्यूज़लेटर
संस्थापक: डा. एस. नागराजन
Six-monthly newsletter named after Prof. K.C. Mehta
Founder Dr. S. Nagarajan

Vol. 40 (2) **July, 2020**

जारीकर्ता/Issued by

भा.कृ.अनु.प.–भारतीय गेहूँ एवं जौ अनुसंधान संस्थान, क्षेत्रीय केन्द्र, फलावरडेल, शिमला–171002 हि.प्र. (भारत)

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Prof. K.C. Mehta (1892-1950)
Founder of the Flowerdale station

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सारांश /Summary

फसल वर्ष 2019–20 के दौरान गेहूँ और जौ के सभी रतुआ रोगों को देखा गया। गेहूँ एवं जौ पीला रतुआ का प्रकोप, गेहूँ उत्पादन करने वाले उतर भारत के कुछ क्षेत्रों के अलावा भारत के अन्य भागों में उल्लेखनीय नहीं रहा। ऑफ–सीजन के दौरान गेहूँ के रतुआ रोगो की व्यापकता कम थी, हालांकि कुछ डाइकोकम गेहूँ में भूरा और काले रतुऐ का संक्रमण देखा गया।

इस फसल वर्ष के दौरान केन्द्र के कर्मचारियों के अलावा 35 से अधिक शोधकर्ताओं द्वारा गेहूँ एवं जौ पर लगने वाले रतुआ रोगों की निगरानी की गयी ओर रतुआ रोग के नमूनों को भारतीय गेहूँ एवं जौ अनुसंधान सस्थान, क्षेत्रीय केन्द्र, फलावरडेल, शिमला में रतुआ प्रभेदों के विश्लेषण के लिए भेजा गया। इस दौरान भारत के 14 राज्यों एवं नेपाल से प्राप्त गेहूँ एवं जौ के 897 रतुआ नमूनों का विश्लेषण किया गया। रतुआ नमूनों के विश्लेषण के आधार पर *पक्सीनिया स्ट्राईफारमिस* के प्रभेद 238एस119 की आवृति अधिकतम (44.06 प्रतिशत) थी। इसके बाद 46एस119 ओर 110एस119 प्रभेदों की पहचान क्रमशः 32.2 और 18.99 प्रतिशत नमूनों में की गयी।

शेष पेज 1 पर.....

कार्यकारी सारांश/Executive summary

पक्सीनिया ट्रीटीसीना के प्रभेदों 77–9, 77–5 और 77–1 की पहचान क्रमशः 50.3, 28.2 और 7 प्रतिशत नमूनों में की गयी। पक्सीनीया ग्रेमिनिस ट्रीटीसाई के प्रभेद 11 की आवृति सर्वाधिक थी जो 88 प्रतिशत नमूनों में देखी गयी। इसके पश्चात प्रभेद 40ए ओर 40–2 की आवृति अधिक थी जिनको क्रमशः 4.7 ओर 3.9 प्रतिशत नमूनों में देखा गया।

वर्ष 2019–20 के दौरान गेहूँ एवं जौ की 3800 से अधिक किस्मों में पौध अवस्था में रतुआ प्रतिरोध के आंकलन का मूल्यांकन किया गया। जिनमें एवीटी की 137 और एनबीडीएसएन/इबीडीएसएन की 173 पंक्तियॉ शामिल है। एवीटी की पंक्तियों में रतुआ रोगों के प्रतिरोध के आंकलन के लिए *पक्सीनिया* प्रजाति के 59 प्रभेदों (पीला रतुआ के 16, काला रतुआ के 21 और भूरा रतुआ के 22 प्रभेद) का उपयोग किया गया। गेहूँ के पीला रतुआ प्रतिरोधी जीन्स (*वाईआर 2, 9, ए,* और *18*) को एवीटी की 95 लाइनों में देखा गया। इस प्रकार 10 भूरा रतुआ प्रतिरोधी जीन्स (*एलआर 1, 2ए, 3, 10, 13, 18, 23, 24, 26* और *34*) तथा 13 काला रतुआ प्रतिरोधी जीन्स (*एसआर 2, 5, 7बी, 8ए, 8बी, 9बी, 9इ, 11, 13, 24, 28, 30* और *31*) को क्रमशः 112 और 120 लाइनों में आंका गया।

एवीटी की किसी भी लाईन में गेहूँ के दोनो भूरा एवं पीला रतुआ के लिए वयस्क अवस्था में रतुआ प्रतिरोध नही देखा गया। एवीटी की प्रविष्ठि डीवीडब्लयू187 में पीला रतुआ के सर्वाधिक पाये जाने वाले तीन प्रभेदों और भूरा रतुए के प्रभेद 77–5 के लिए वयस्क पौध अवस्था में रतुआ प्रतिरोध देखा गया। इसी प्रकार एचडी3086 में पीला रतुआ के तीनो प्रभेदों तथा भूरा रतुए के प्रभेद 104–2 के लिए और प्रविष्ठि एचडी2223 में पीला रतुआ के तीनो ओर भूरा रतुआ के प्रभेदों 77–5 और 77–9 के लिए वयस्क पौध अवस्था में रतुआ प्रतिरोध देखा गया।

एनबीडीएसएन की 129 प्रविष्ठियों में रतुआ प्रतिरोध का मूल्यांकन जौ पर लगने वाले *पक्सीनिया* के विभिन्न प्रभेदों के खिलाफ किया गया। इन में से कोई भी प्रविष्ठि काला, भूरा और पीला रतुआ के सभी प्रभेदों के लिए प्रतिरोधी नहीं थी। एनबीडीएसएन की दस पंक्तियां भूरे ओर पीले रतुए के लिए, एक पंक्ति काले और पीले रतुए के लिए और चार पंक्तियां भूरे ओर काले रतुए के लिए प्रतिरोधी थी। इबीडीएसएन की 44 पंक्तियों में रतुआ रोग प्रतिरोध का मूल्यांकन सर्वाधिक पाये जाने वाले रतुआ प्रभेदो के खिलाफ किया गया। किसी भी प्रविष्टि में तीनों रतुओ रोगों के लिए प्रतिरोधकता नहीं देखी गयी, हालांकि 9 पंक्तियों में भूरा और पीला रतुआ के लिए जबकि एक पंक्ति में काला और पीला रतुऐ के लिए और 2 पंक्तियों में भूरा और तना रतुआ के सभी प्रभेदों के लिए प्रतिरोधकता पायी गयी।

हाल ही में अनुमोदित की गयी गेहूँ की किस्मों में भूरा रतुआ प्रतिरोधी जीन *एलआर68/एलटीएन4* की उपस्थिति की जांच जीन से जुडे हुए एसटीएस मार्कर की सहायता से की गयी। अन्य जीनों की पहचान भी उनसे

जुडे हुए मार्करों की सहायता से की गयी। रतुआ प्रतिरोधी किस्मों एवं जेनेटिक स्टॉक बनाने के लिए 4 अभिजनन (ब्रीडिंग) पापुलेशन को अगली पीडियों में पहुंचाया गया और 15 नये क्रॉस बनाये गये।

उतर–पूर्वी भारत, बंगलादेश और नेपाल से प्राप्त भूरा रतुआ के नमूनों में 5 नये प्रभेदों की पहचान की गयी। इन प्रभेदों को रोग उत्पन्न करने की क्षमता तथा जैव–आणविक अध्ययन के आधार पर वर्गीकृत किया गया। पक्सीनीया स्ट्राईफारमिस के जीनोम आधारित एसएसआर मार्कर बनाये गये जिनको भारत में पाये जाने वाले पीला रतुआ प्रभेदों के अध्ययन के लिए उपयोग में लाया गया। इनमें से 24 मार्कर 11 प्रभेदों के लिए पौलीमारफिक पाये गये। काला रतुआ के प्रभेदों में परिवर्तनशीलता का अध्ययन *पक्सीनिया गेमिनिस ट्रीटीसाई* विशिष्ठ एसएसआर मार्करों की सहायता से किया गया। 30 एसएसआर मार्करों में से 20 को काला रतुआ के चयनित प्रभेदों के लिए पोलमार्फिक पाया गया तथा बाद में इन मार्करों का उपयोग सभी प्रभेदों के अध्ययन के लिए किया गया।

120 से अधिक रतुआ प्रभेदों के संग्रह को विभिन्न अवस्थाओं में संरक्षित किया गया। इसमें से कुछ के नाभिकीय एवं थोक इनाकुलम को 45 से अधिक केन्द्रों/वैज्ञानिकों को गेहूँ के रतुआ रोगों पर शोध के लिए भेजा गया । गेहूँ में लगने वाले विभिन्न रोगों की निगरानी करने के लिए गेहूँ रोग निगरानी नर्सरी (डब्ल्यूडीएमएन/टीपीएन) और सार्क–गेहूॅ रोग निगरानी नर्सरी को क्रमशः भारत में 37 स्थानों पर तथा सार्क देशों में 28 स्थानों पर आयोजित किया गया।

All the rusts of wheat and barley were observed in India and Nepal during 2019-20. Barring the widespread occurrence of stripe rust in few of the wheat growing areas of northern India, there was no noticeable occurrence of rusts of wheat and barley in other parts of India. Prevalence of rusts was low in off-season wheat, however, some of the dicoccum germplasm supported substantial leaf and stem rust infection.

Wheat and barley crop was monitored for rust diseases by more than 35 wheat researchers besides the staff of centre and rust samples were received at ICAR-Indian Institute of Wheat and Barley Research, Regional Station, Shimla for pathotype analysis. A total of 897 samples of three rusts of wheat and barley from fourteen Indian states, and Nepal were analyzed during 2019-20. Pathotyping of rust samples revealed that the frequency of *Puccinia striiformis tritici* (Pst; Yellow rust) pathotype 238S119 was maximum (44.06%) followed by pathotype 46S119 (33.2%) and 110S119 in 18.98% of the analyzed samples. Pathotypes 77-9, 77-5 and 77-1 were the most predominant in *P.*

triticina (Pt; brown rut) population and were identified in 50.3, 28.2 and 7.1 % of the samples, respectively. Pathotype 11 of *P. graminis tritici* (Pgt; black rust) was the most frequent and was observed in 88.2% of the samples analyzed followed by 40A and 40-2 which were recorded in 4.7 and 3.9% samples, respectively.

To identify rust resistance, more than 3800 lines of wheat and barley were evaluated at seedling stage during 2019-20. Among these, 310 lines including 137 of AVT and 173 of NBDSN/EBDSN were subjected to multipathotype screening under controlled light and temperature conditions. To know the rust resistance of wheat lines of AVT at seedling stage, 59 pathotypes (Sixteen pathotypes of stripe rust, 21 of stem and 22 of leaf rust) of three species of *Puccinia* on wheat were used for screening. Four *Yr* genes (*2, 9, A,* and *18*) were inferred in 95 advance wheat lines. Similarly, 10 *Lr* genes (*Lr1, Lr2a, Lr3, Lr10, Lr13, Lr18, Lr23, Lr24, Lr26* and *Lr34*) and 13 *Sr* genes (*Sr2, Sr5, Sr7b, Sr8a, Sr8b, Sr9b, Sr9e, Sr11, Sr13, Sr24, Sr28, Sr30 and Sr31*) were characterized in 112 and 120 AVT lines, respectively.

None of the lines showed appreciable APR to both leaf and stripe rusts. AVT entry DBW187 possessed APR to all the three predominant and virulent pts. of stripe rust and pt. 77-5 of leaf rust. Likewise, HD3086 conferred APR to stripe rust pts. and pathotype 104-2 of leaf rust whereas HD3332 to stripe rust pts. and pts.77-5 and 77-9 of leaf rust.

A total 129 lines of NBDSN were evaluated against the different pathotypes of *Puccinia* spp on barley. None of the NBDSN and EBDSN entries was resistant to all the tested pathotypes of Pst, Pt and Pgt. Twelve lines were resistant both to leaf and stripe rusts, one to stem and stripe rusts whereas 4 to leaf and stem rusts. Forty-four EBDSN lines were evaluated for resistance to three rusts by using all the virulent and predominant pathotype of each. Resistance to all the rusts was not found in any of the lines. However, 9 lines were resistant to leaf and stripe rusts, 1 to stem and stripe rusts, 2 to leaf and stem rusts.

Recently released wheat varieties were screened for the presence of leaf rust resistance gene *Lr68/Ltn4* using *Lr68* linked STS marker (CsGS-STS-*Lr68*). Presence of other genes was also confirmed using the molecular markers linked to them. Generation advancement of 4 breeding populations was completed and 15 new crosses for development of rust resistant germplasm, genetic stocks etc. were also attempted.

Five new pathotypes of *P. triticina* (wheat leaf rust) were described from North eastern India, Bangladesh and Nepal. Distinction, both at physiological and molecular level was studied. Genome based, new 89 SSR primers were got synthesized and studied for differentiating pathotypes of *P. striiformis* in India. Twenty-four of these primers were polymorphic to the 11 pathotypes studied. Molecular variability among twenty-nine black rust pathotypes was also looked into using selected *Puccinia graminis tritici* specific SSR primers. Among 30 black rust specific SSR markers, twenty were found to be polymorphic to selected pathotypes of *Puccinia graminis tritici*. The polymorphic primers were further tested against all the black rust pathotypes.

A collection of more than 120 pathotypes of different rust pathogens was maintained in live culture as well as cryo-preserved. Strategically less important pathotypes were cryopreserved in sufficient quantity and live cultures discontinued for 26 pathotypes. Nucleus/bulk inoculum of different pathotypes of rust pathogen was supplied to more than 45 Scientists/centers for conducting wheat and barley rust research elsewhere in India. To monitor, the occurrence of wheat disease, wheat disease monitoring nursery (WDMN/TPN) and SAARC wheat disease monitoring nursery were organized and conducted at more than 37 locations in India as well as 28 locations across the six SAARC countries, respectively.

1. Incidence of wheat and barley rusts in India

All the rusts of wheat and barley were observed in India and Nepal during crop season 2019-20. The first occurrence of yellow rust was reported from Anandpur Sahib Block in district Rupnagar (Punjab) on 26th December, 2019, which was followed by few reports of yellow rust from foot hills in Punjab during January. During February-

March yellow rust was detected in small foci from other parts of Punjab, Haryana, Himachal Pradesh, Rajasthan and Uttarakhand. Barring the widespread occurrence of stripe rust in few of the wheat growing areas of northern India, there was no noticeable occurrence of rusts of wheat and barley in other parts of India. Prevalence of rusts was low in off-season wheat, however, some of the dicoccum germplasm supported substantial leaf and stem rust infection. Incidence of leaf rust was observed in some farmer's field in area of Belagavi, Bagalkot, Dharwad and other areas in Karnataka; Anandpur Sahib (Rupnagar) in Punjab; Satara, Pune, Niphad, Nashik and other areas of Maharashtra, Indore, Hoshangabad and other parts of Madhya Pradesh. Similarly, Stem rust was observed in Satara, Pune, Niphad, Nashik and other other of Maharashtra and Belagavi, Bagalkot, Dharwad and Gadag districts in Karnataka.

The wheat and barley rusts were kept under check with the help of cooperators, through exhaustive rust surveillance in different wheat growing areas of India and neighboring countries. Besides the staff of centre, more than 35 wheat researchers (Table 1) from different institution/State/Countries helped in effective monitoring of wheat and barley rust diseases and sending wheat and barley rust samples. Wheat monitoring teams of different zones also reported the occurrence of wheat rusts in the areas visited by them.

Table 1. List of actively involved co-operators in monitoring wheat and barley rusts during 2019-20.

Cooperators	Organization/State
Indian States	
AA Patel	SDAU, Vijapur, Gujarat
AK Basandrai	CSKHPKV, Malan, Kangra, H.P.
Akhilesh Singh	RRS-CSKHPKV, Dhaulakuan, HP
Anjum Varshney	State Agriculture Department, Noida, Uttar Pradesh
BC Game	ARS, Niphad, Maharashtra
DA Gadekar	ARS, Niphad, Maharashtra
Deepshikha	GBPUAT, Pantnagar, US Nagar, Uttarakhand
DP Walia	RS, ICAR-IARI, Shimla, Himachal Pradesh
GM Hegde, SV Kulkarni	UAS, Dharwad, Karnataka
Hanif Khan	ICAR-IIWBR, Karnal
Hembram Satyajit	UBKV, Coochbihar, WB
Jaspal Kaur	PAU, Ludhiana, Punjab
K H Dhabi	JAU, Junagarh, Gujarat
KK Mishra	ICAR-VPKAS, Almora, Uttarakhand

KK Mishra	JNKVV, Powarkheda, MP
M Sivasamy	IARI-RS Wellington, T. N.
MK Pandey	SKUAST, Jammu, J&K
P Nallathambi	IARI-RS Wellington, T. N.
PL Kashyap	ICAR-IIWBR, Karnal
Pradeep Shekhawat	RARI, Durgapura, Jaipur, Rajasthan
Prakash, T L	RS, ICAR-IARI, Indore, Madhya Pradesh
Rajbeer Yadav	IARI, Pusa, New Delhi
Rajender Singh Beniwal	CCSHAU, Hisar, Haryana
RL Meena	KVK Dausa, Rajasthan
Sabana Parveen	Syngenta Pvt Ltd. Karnal, Haryana
Sachin Upamanyu	CSKHPKV, Malan, HP
SH Wani	Kudwani, JK
SK Jain	BIBSM, Raipur, C.garh
SK Rana	Palampur, HP
Sudheer Kumar	ICAR-IIWBR, Karnal
Sudhir Navathe	Aghrakar Research Institute, Pune, Mah
Sunita Mahpatra	Kalyani, West Bengal
Vijay Rana	CSKHPKV, Malan, Himachal Pradesh
VK Srivashtav	Ghaziabad, UP
VK Vikas	IARI-RS Wellington, T. N.
Other Countries	
BN Mahto	NARC, Kathmandu, Nepal
Suraj Vaidya	NARC, Kathmandu, Nepal

2. Monitoring pathotype distribution of *Puccinia* species on wheat and barley

A total of 897 samples of three rusts of wheat and barley have been pathotyped so far from India and Nepal. Following is the detail of pathotypes analyzed in 897 samples of wheat and barley rusts during the crop season 2019-20.

i. Stripe (yellow) rust of Wheat and Barley (*Puccinia striiformis* f. sp. tritici, *Pst* and *Puccinia striiformis* f. sp. *hordei, Psh*)

During the year 305 samples of wheat stripe rust were analyzed from seven states of India and Nepal on the sets of differentials. The Indian population of *P. striiformis* is avirulent on *Yr5, Yr10, Yr15,* and *YrSp*. Pathotype 238S119 was the most predominant among the seven pathotypes occurring on wheat and was observed in 44.06% samples. This pathotype is virulent on *Yr2, Yr3, Yr4, Yr6, Yr7, Yr8, Yr9, Yr11, Yr17, Yr18, Yr19, Yr21, Yr22, Yr23, Yr25, YrA* and Riebesel 47/51. The population of 46S119 has declined to 33.2% followed by 110S119 in 18.98% of the samples. Among these, pathotype 238S119 is most virulent as it has additional virulence for Suwon x

Omar92 and Riebesel when compared with pt. 46S119. Other pathotypes 14S64, 6S0, 7S0 and 47S103(T) have occurred in between 0.3% to 1.2% samples (Table 2).

In stripe rust of barley (*P. striiformis hordei*), 10 samples were analyzed from Himachal Pradesh, Rajasthan and Nepal. Pathotypes 0S0 (57) and 4S0 (G) were most predominant whereas 1S0 (M) was recorded in one sample only (Table 2).

ii. Stem (black) rust of Wheat (*Puccinia graminis* f.sp. *tritici,* Pgt)

In general, wheat stem rust occurred in Peninsular and Central India. Seven pathotypes were identified in 127 samples of stem rust pathotyped from six states (Tamil Nadu, Karnataka, Maharashtra, Gujarat, Madhya Pradesh and Uttarakhand) and Nepal. Pathotype 11 (79G31), virulent on *Sr2, Sr5, Sr6, Sr7b Sr9a, Sr9b, Sr9c, Sr9d, Sr9f, Sr9g, Sr10, Sr13, Sr14, Sr15, Sr16, Sr17, Sr18, Sr19, Sr20, Sr21, Sr28, Sr29, Sr30, Sr34, Sr36, Sr38,* and *SrMcN* was the most predominant and was recorded in 88.2% of the samples analyzed. Other six pathotypes were identified in few samples only. While pathotype 62G29 (40A) occurred in 4.7%, pt. 58G15-3 (40-2) was observed in 3.9% of the samples. Remaining 4 pathotypes were detected in 0.78% samples each (Table 3).

iii. Leaf (brown) rust of Wheat (*Puccinia triticina,* Pt)

A total of 465 samples of wheat leaf rust were pathotyped during 2019-20 from 14 states of India and Nepal. Twenty-three pathotype of *P. triticina* were observed in varying frequencies. Indian population of *P. triticina* was avirulent on *Lr24, Lr25, Lr29, Lr32, Lr39, Lr45* and *Lr47*. Pathotype 77-9 (121R60-1) virulent on *Lr1, Lr3, Lr10, Lr11, Lr12, Lr13, Lr14a, Lr14b, Lr14ab, Lr15, Lr16, Lr17a, Lr17b, Lr18, Lr20, Lr21, Lr22a, Lr22b, Lr23, Lr26, Lr27+31, Lr30, Lr33, Lr34, Lr35, Lr36, Lr37, Lr38, Lr40, Lr44, Lr46, Lr48, Lr49,* and *Lr67*, followed by 77-5 (121R63-1) were the most widely distributed pathotypes and were observed in 14 and 11 states of India, respectively, and Nepal. Pathotype 77-9 was identified in 50.3% of pathotyped samples followed by 77-5 (28.2%), 77-1 (109R63) in 7.1% and 104-2 (21R55) in 3.2% samples. Remaining 19 pathotypes were each detected in less than 1% of the analyzed samples (Table 4).

Ten pathotype were identified in 20 samples received from Nepal. Pathotype 77-9 and 77-5 were most frequent followed by 77-1. The remaining pathotype were observed in one sample each (Table 4).

Table 2. Pathotype distribution of yellow rust (*Puccinia striiformis*) in India and neighboring countries during 2019-20.

S. No.	State/country	Number of isolates analyzed	Pathotypes observed									
			P. striiformis f. sp.*tritici*				*P. striiformis f. sp.hordei*					
			238S119	110S119	46S119	14S64	6S0	7S0	47S103 (T)	1S0 (M)	0S0 (57)	4S0 (G)
1.	Himachal Pradesh	163	71	20	57	02	01	04	-	01	03	04
2.	Punjab	114	48	28	38	-	-	-	-	-	-	-
3.	Haryana	09	06	01	02	-	-	-	-	-	-	-
4.	Rajasthan	09	03	04	01	-	-	-	-	-	01	-
5.	Uttar Pradesh	01	-	01	-	-	-	-	-	-	-	-
6.	Uttarakhand	01	01	-	-	-	-	-	-	-	-	-
7.	Delhi	02	01	01	-	-	-	-	-	-	-	-
8.	Nepal	06	-	01	-	-	-	-	04	-	01	-
Total		**305**	**130**	**56**	**98**	**02**	**01**	**04**	**04**	**01**	**05**	**04**

Table 3. Pathotype distribution of black rust (*Puccinia graminis* f. sp. *tritici*) in India and neighboring countries during 2019-20.

S. No.	States/Countries	Number of isolates analyzed	Pathotypes observed¥						
			11 (79G31)	**11A** (203G15)	**15-1** (123G15)	**40A** (62G29)	**40-2** (58G13-3)	**42** (19G35)	**122** (7G11)
1	Gujarat	14	14	-	-	-	-	-	-
2	Karnataka	28	25	01	-	-	01	01	-
3	Madhya Pradesh	59	56	-	-	-	03	-	-
4	Maharashtra	17	16	-	01	-	-	-	-
5	Tamil Nadu	07	-	-	-	06	01	-	-
6	Uttarakhand	00	-	-	-	-	-	-	-
7	Nepal	02	01	-	-	-	-	-	01
Total		**127**	**112**	**01**	**01**	**06**	**05**	**01**	**01**

¥North American equivalents 11 (RRTSF), 11A (RHTSF), 15-1 (TKTSF), 40A (PTHSC), 40-2 (PKRSC),42 (HKHSC), 122 (RRHSC) based on Jin *et al*., *Plant Dis.* 2008, 92: 923-6.

Table 4. Pathotype distribution of brown rust (*Puccinia triticina*) in India and neighboring countries during 2019-20.

S. No.	State/Country	No. of isolates Analyzed	Pathotypes observed¥																							
			10-1 (56R27)	12-1(5R37)	12-3 (49R37)	12-4 (69R13)	12-5 (29R45)	12-8 (49R45)	20(5R27)	77-1 (109R63)	77-2 (109R31-1)	77-5 (121R63-1)	77-6 (121R55-1)	77-9 (121R60-1)	77-9+Raj1555	77-11	104-1 (21R31-1)	104-2 (21R55)	104A (21R31)	107-1 (45R35)	162 (93R7)	162-1(93R47)	162-2 (93R39)	162-5	1R31
1	Himachal Pradesh	15	-	-	-	-	-	-	-	-	-	2	1	3	-	-	-	8	-	-	1	-	-	-	-
2	Jammu & Kashmir	3	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-
3	Punjab	23	-	-	-	-	-	-	-	1	-	2	-	19	1	-	-	-	-	-	-	-	-	-	-
4	Uttar Pradesh	6	-	-	-	-	-	-	-	-	-	2	-	4		-	-	-	-	-	-	-	-	-	-
5	Uttarakhand	14	-	-	-	1	-	-	-	1	-	6	-	5	-	-	-	-	1	-	-	-	-	-	-
6	Madhya Pradesh	47	-	-	-	-	3	-	-	1	-	17	-	19	-	-	-	2	1	-	-	2	2	-	-
7	Chhatisgarh	8	-	-	-	-	-	-	-	1	-	-	-	6	-	-	-	-	1	-	-	-	-	-	-
8	Bihar	8	-	-	-	-	-	-	-	-	-	1	-	7	-	-	-	-	-	-	-	-	-	-	-
9	West Bengal	31	-	-	1	1				-	-	5	-	21	3	-	-	-	-	-	-	-	-	-	-
10	Assam	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
11	Gujarat	12	-	-	-	-	-	-	-	-	-	5	-	6	-	-	-	1	-	-	-	-	-	-	-
12	Maharashtra	62	-	-	-	-	-	-	-	1	-	11	-	47	-	-	-	1	-	2	-	-	-	-	-
13	Karnataka	87	-	2	-	-	1	1		9	-	12	-	53	-	5		2	-	-	-	-	-	2	-
14	Tamil Nadu	128	-	-	1	-	-	4	1	16	-	62	1	36	-	-	1	-	-	-	1	-	-	-	5
Other country																										
1	Nepal	20	1	1	-	-	1	1	-	3	1	5	-	5	-	-	1	1	-	-	-	-	-	-	-
Total		**465**	**1**	**3**	**2**	**2**	**5**	**6**	**1**	**33**	**1**	**131**	**2**	**234**	**4**	**5**	**2**	**15**	**3**	**2**	**2**	**2**	**2**	**2**	**5**

¥ North American Notation (Kolmer et al., Phytopathology, 2011, 101: 870-877)

10-1 (SGJPN), 12-1 (FHPNM), 12-3 (FHTNL), 12-4 (FGTRM), 12-5 (FHTPM), 12-8 (FHRNL), 20 (SGQPL), 77-1 (THTTB), 77-2 (TGTTL), 77-5 (THTTM), 77-6 (THTTL), 77-9 (MHTKL), 104-1 (PGTST), 104-2 (PHTTL), 104A (MGTDF), 107-1 (JCGPL), 162 (KGTSB), 162-1 (KHTTM), 162-2 (KHTTL), 162-5 (KHTPM)

3. Seedling resistance test (SRT) in wheat against virulent pathotypes of rust pathogens and characterization of rust resistance genes

For identifying the sources of rust resistance, more than 3800 wheat and barley lines including 137 entries of advanced wheat material (AVT), 173 lines of NBDSN & EBDSN, and other wheat and barley material from Indian Breeders/Geneticists, material from CIMMYT, ICARDA etc. were evaluated (Table 5) at seedling stage under controlled conditions using an array of pathotypes of stem (*P. graminis* f. sp. *tritici*), leaf (*P. triticina*) and stripe rust (*P. striiformis* f.sp. *tritici*) possessed different avirulence/virulence structures. To identify rust resistant lines of wheat & barley and characterize rust resistance genes in wheat lines using gene matching technique, one-week old seedlings were inoculated with 59 pathotypes of three species of *Puccinia*. Sixteen pathotypes of stripe rust, 21 of stem and 22 of leaf rust which are most virulent and predominant, were used for evaluation. The inoculated seedlings were incubated in saturated humid chambers for 48 hours at optimum temperature and light for each of the rust. Subsequently these plants were transferred on to the greenhouse benches where sufficient day light (more than 5,000 Lux) and temperature of 16±2^{0}C (stripe rust), 22±2^{0}C (leaf rust) 24±2^{0}C (stem rust) and relative humidity of 80-100% were maintained.

Table 5. Details of wheat and barley materials used for Seedling Resistance Test during 2019-20

S. No.	Description	No of Lines	Pathotypes		
			Black rust	Brown rust	Yellow rust
1	Wild wheat lines (Sindhu Sareen, IIWBR, Karnal)	08	-	-	238S119, P, T, 46S119, 110S119
2	Wild wheat lines (Sindhu Sareen, IIWBR, Karnal)	12	-	Multiple	-
3	Wild wheat lines (Sindhu Sareen, IIWBR, Karnal)	34	Multiple	-	-
4	DP Walia, IARI, Shimla	54	-	-	238S119, 110S247, 110S119, Mix
5	AVT Material	137	Multiple	Multiple	Multiple
6	Wheat lines (Hanif Khan, IIWBR, Karnal)	152	-	12-5,77-5, 77-9, 104-2	Multiple
7	Wheat Lines	65	-	12-5,77-5, 77-	238S119, T, 46S119,

	(Vijay Rana, CSKHPKV, Malan, HP)			9, 104-2	110S119
8	Wheat lines (Satish Kumar, IIWBR, Karnal)	24	-	-	238S119, T, 46S119, 110S119, 78S84, P
9	NBDSN & EBDSN	173	11, 40A, 21A-2, 117-6, 122	Multiple	57, 24, M, G, Q, 6S0, 7S0
10	Barley Lines (Joginder Singh, IIWBR, Karnal)	60	-	H1, H2, H3, H4, H5	57, 24, M, G, Q, 6S0, 7S0
11	Australian Barley lines (KS Sandhu, PBI, UoS, Cobbittyy, Australia	100	-	-	57, G
12	Australian wheat lines (Hanif Khan, IIWBR, Karnal)	2150	-	-	110S119, 238S119
13	Wheat lines (VK Singh, IARI, New Delhi)	55	-	Multiple	Multiple
14	Barley Lines (Madhu Patial IARI, RS, Tutikandi, Shimla)	27	11, 21A-2, 40A, 122	H1, H2, H3, H4, H5	57, 24, M, G, 7S0
15	Wheat Lines (Madhu Patial IARI, RS, Tutikandi, Shimla)	33	-	Multiple	Multiple
16	Wheat Lines (Vikas VK, IARI, Wellington, TN)	4	11, 40A, 40-3	77-5, 77-9, 104-2	110S119, 238S119, 110S84
17	Wheat lines (SK Sharma, NBPGR, New Delhi	400	11, 40A, 40-3, 117-6	12-5, 77-5, 77-9, 104-2	-
18	Wheat Lines, (CN Mishra, IIWBR, Karnal, CRP project)	246	11, 40A, 117-6, 295	12-5, 77-5, 77-9, 104-2	-
19	Wheat lines (Shailendra Sharma, CCS Meerut, UP)	105	Multiple	Multiple	-
20	Wheat lines (M Sivasamy, IARI, Wellington, TN)	32	15-1, 40A, 40-1	77-5, 77-9, 104-2	
Total	**3871**				

Rust resistance in AVT lines

None of the lines of AVT was resistant to all the rusts (Table 6). PBW813 was resistant to stem and stripe rusts. Whereas HI1641, HI1642 and MACS 6752 were resistant to leaf and stem rusts.

Table 6. Rust resistance in advanced wheat material (AVT: 2019-20)

Rusts	No. of lines	Wheat lines
Stem and stripe rusts	1	PBW813
Leaf and stem rusts	3	HI1641, HI1642, MACS6752
Leaf rust only	20	CG1029*, GW513, GW519, HD2864, HD3090 (C), HI1544, HI1633, HI1634Q, HI1636, HI1637, MACS 4087 (D), MACS 6747, MACS 6749, MACS3949 (D) (C), MACS6222 (C), PBW550 (C), PBW771 (C), PBW840, RAJ4541B, UAS446 (D) (C)
Stem rust only	3	DBW110, DBW303, DBW332

Twenty other lines were resistant to leaf and 3 to stem rust only. In addition, 25 lines having *Sr31/Lr26/Yr9* were resistant to stem rust whereas some to leaf rust also (Table 6).

Rust resistance genes in AVT lines (Gene postulation)

Wheat rust resistance genes (*Lr, Sr, Yr*) were characterized using gene matching technique. Rust resistance genes were characterized in those lines where differential host-pathogen interaction was present. In addition, linked characters, morphological markers, characteristic infection types and pedigree also formed the basis for postulating rust resistance genes in absence of host-pathogen differential reactions.

Yr-genes

Among the 137 lines of AVT, *Yr* genes were characterized in 94 lines. *Yr* genes were postulated in lines where differential interactions were observed and in other cases tight linkage of *Yr* genes to resistance genes to other rusts also facilitated to infer the presence of a resistance gene. Four *Yr* genes viz. *Yr2*, *Yr9*, *YrA* and *Yr18* contributed for yellow rust resistance in India. Among the postulated *Yr* genes *Yr2* was most common and was characterized in more than half of the lines. *Yr9* on the other hand occurred in 25, *YrA* in 15 and *Yr18* in one line only (Table 7).

Table 7. *Yr*-genes postulated in AVT entries during 2019-20

Yr gene	No. of lines	Detail of lines
Yr2+	61	CG1029, DBW88 (C), DBW110, DBW187 (I) (C), DBW252 (I) (C), DBW290, DBW291, DBW296, DBW303, DBW327, DBW328, DBW329, DBW330, DBW333, DDW48 (D), GW513, GW519, HD2864, HD2967 (C), HD3059 (C), HD3086 (C), HD3171 (C), HD3249 (I) (C), HD3293 , HD3298 , HD3331 , HD3332, HD3377, HI1605 (C), HI1612 (C), HI1628 (I) (C), HI1646, HI8627 (D), HI8818 (D), HPW349 (C), HPW474, HUW838, HW1098 (C), MACS3949 (D) (C), MACS6222 (C), MP1361, MP3288, MPO1357 (D), NIDW1149 (D), PBW644 (C), PBW803, PBW811, PBW812, RAJ4083 (C), RAJ4541, TAW155, UAS3008, UAS472 (D), VL2036, VL892 (C), WH1080 (C), WH1105 (C), WH1124 (C), WH1252, WH1264, WH1270
Yr9+	17	DBW39 (C), DBW173 (C), DBW222 (I) (C), HD3090 (C), HI1633, HI1634, HS507 (C), HS668, HS679, HS680, HS681, PBW550 (C), UP3033, VL907 (C), VL3024, WH1021 (C), WH1142 (C)
Yr9+18+	01	HD2733 (C)
Yr9+A+	07	HD3043 (C), HD3334, K1317 (C), PBW771 (I) (C), PBW840 (M), VL3022, VL3023
YrA+	08	DBW332, HI1642, HPW473, HS490 (C), HS562 (C), JAUW672, MP1358, UP2369
Total	**94**	

Lr-genes

Ten *Lr* genes viz. *Lr1, Lr2a, Lr3, Lr10, Lr13, Lr18, Lr23, Lr24, Lr26* and *Lr34* were characterized in 112 lines. *Lr10* was the most commonly occurring leaf rust resistance and was characterized in highest number of lines (37) followed by *Lr13* (30 lines), *Lr1* (29 lines) and *Lr26* (25 lines). *Lr24* was also postulated in 12 lines. Among these *Lr13* becomes effective at higher temperature. While *Lr2a/Sr30* and *Lr3* were inferred in 6 lines each, *Lr18* was postulated in 2, *Lr34* in 1 line only. *Lr2a/Sr30* are closely linked and we have differentiating pathotypes for both the resistance genes. Most of the genes occurred in combination and many of the lines have leaf rust resistance derived from 3 or more *Lr* genes (Table 8).

Table 8. ***Lr*****-genes postulated in AVT entries during 2019-20**

Lr gene/s	No. of lines	Lines/Varieties
Lr13+	12	DBW222, DBW303, DDK1029, HD2932, HI1605, HI8627, MP3336, PBW804, PBW811, RAJ4083, UAS466, WH1105, WH1252
Lr13+1+	6	DBW329, DBW332, GW322, K1006, PBW644, UAS3008,
Lr13+3+	3	HD3059, HPW473, WH1080
Lr13+10+	10	DBW252, DBW290 DBW330, HD3332 HD3249, HD3293, HI1628, HPW349, VL892, WH1264
Lr13+10+1+	5	DBW291, DBW333, HI1646, MP1361, NIAW3170
Lr13+10+1+2a	1	TAW155
Lr13+10+3+	4	DBW88, HD3086, HUW838, WH1124
Lr13+10+3+2a	1	HPW474
Lr18+	2	DDW49, HW1098
Lr23+	10	AKDW2997-16, HD2967, HI1612, HI8805, HS562, MACS5055, MPO1357, NIDW1149, UAS428, WH1270
Lr23+1+	3	DBW327, HD3377, HD3378
Lr23+2a+	1	HD3298
Lr23+3+2a+	2	PBW803, PBW812
Lr23+10+	3	DBW110, HI8818, MP1358
Lr23+10+1+	3	DBW187, DBW331, DBW328
Lr23+10+2a+	1	VL2036
Lr23+10+3+	1	HS490
Lr23+13+	4	JKW261, JAUW672, MPO1357, WHD964
Lr23+13+3+	1	HD3331
Lr23+13+10+	2	HD3171, DBW296
Lr24+	12	CG1029, GW513, GW519, HD2864, HI1636, HI1637, HI1544, MACS6222, MACS6747, MACS6749, MP3288, RAJ4541
Lr26+	6	HD3090, HI1633, HI1634, PBW550, PBW840, VL907
Lr26+1+	3	HS507, K1317, WH1021
Lr26+10+3+	2	DBW173, UP3033
Lr26+23+	3	DBW222, HD3043, VL3023
Lr26+23+1+	5	HD3334, HS679, HS681, PBW771, VL3022
Lr26+23+1+3	1	HS668
Lr26+23+10+	1	DBW39
Lr26+23+10+1+	2	HS680, VL3024
Lr26+23+10+3+	1	WH1142
Lr26+34+	1	HD2733
Total	**112**	

Sr-genes

Thirteen stem rust resistance genes (*Sr2, Sr5, Sr7b, Sr8a, Sr8b, Sr9b, Sr9e, Sr11, Sr13, Sr24, Sr28, Sr30* and *Sr31*) were characterized in 120 AVT lines (Table 9). *Sr* genes *Sr2* and *Sr11* were postulated in 43 AVT entries. *Sr31*, linked with *Lr26* and *Yr9* and conferring resistance to all the known Pgt pathotypes in Indian subcontinent, was postulated in 25 AVT entries. *Sr*-genes *Sr24, Sr28, Sr5, Sr13* and *Sr7b* were characterized in 12, 4, 18, 12 and 31 entries, respectively. *Sr30, Sr9b, Sr8a* were inferred in seven entries each. Most of the *Sr* genes occurred in the combination with other genes. Entry DBW252 possessed a combination of maximum four genes i.e. *Sr5+8a+11+2+* (Table 9).

Table 9. *Sr*-genes postulated in AVT entries during 2019-20

Sr gene/s	Number of lines	Detail of lines
Sr31+5+2+	01	WH1021 (C)
Sr31+5+	07	HD3334, HS507 (C), HS679, HS681, PBW840M, UP3033, VL3024
Sr31+2+	08	DBW39 (C), HD2733 (C), HD3043 (C), HD3090 (C), K1317 (C), PBW550 (C), VL907 (C), WH1142 (C)
Sr31+	09	DBW173 (C), DBW222(I) (C), HI1633*, HI1634[Q*], HS668, HS680, PBW771(I)(C), VL3022, VL3023
Sr24+2+	02	HI1544, MP3288
Sr24+	10	CG1029*, GW513, GW519, HD2864, HI1636, HI1637, MACS6222 (C), MACS6747, MACS6749, RAJ4541[B]
Sr30+5+	04	HPW474, PBW803, TAW155, VL2036
Sr30+11+	02	PBW812, VL892 (C)
Sr30+	01	HD3298*
Sr28+9b+	01	HS490 (C)
Sr28+11+	02	DBW330, DBW333
Sr28+	01	MP1361
Sr8a+9b+2+	01	HS562 (C)
Sr8a+11+2+	01	HD2967 (C)
Sr8a+11+	01	PBW813
Sr8b+9b+11+	01	K1006 (C)

Sr8a+2+	01	NIAW3170(I) (C)
Sr5+8a+11+2+	01	DBW252(I) (C)
Sr5+8a+11+	02	HI1646, HUW838#WB
Sr5+11+7b	01	DBW291
Sr5+11+	03	DBW187(I) (C), DBW328, UAS3008
Sr9e+7b+	01	WH1252
Sr9e+2+	02	HI8627(d), WH1080 (C)
Sr9e+	01	DBW331
Sr9b+11+	01	PBW811
Sr13+5+	01	DBW327
Sr13+9b+	02	DBW290, JAUW672
Sr13+11+2+	01	HI8805(d)(I) (C)
Sr13+7b+	06	DBW296, HD3331#WB, HD3332, JKW261, MACS5055, PBW804
Sr13+	02	HD3293*, WH1270*
Sr11+9b+	01	DBW329
Sr11+7b+2+	02	DDW47(d)(I), HD3171 (C)
Sr11+7b+	06	DDK1058, HD3378, HI8818(d), MACS4087(d), MACS5054, MPO1357(d)[Q]
Sr11+2+	13	DBW88 (C), DDK1029 (C), GW322 (C), HD3059 (C), HD3249(I) (C), HW1098(C), MP3336, NIDW1149(d)*, PBW644 (C), UAS446(d) (C), UAS466(d)(I), UAS472(d), WH1105 (C)
Sr11+	05	HD2932 (C), HI1605 (C), HI8823(d), MP1358, RAJ4083 (C)
Sr7b+2+	08	AKDW2997-16(d) (C), DDW48(d)Q*, DDW49(d)Q*, HD3086 (C), HI1612 (C), HPW349 (C), MACS3949(d) (C), WH1124 (C)
Sr7b+	07	DDK1059, HD3377[B], HPW473, UAS428(d) (C), UP3069, WH1264, WHD964(d)
Sr2+	01	HI1628(I) (C)
Total	**120**	

4. Race specific Adult Plant Resistance (APR) in AVT entries (2019-20)

The AVT lines of wheat for 2019-20 were screened against the most predominant and virulent pathotypes of *P. triticina* and *P. striiformis*. These evaluations were conducted under polyhouses equipped with temperature and light adjustments. Proper checks including differentials, resistance genes and seedlings of AVT lines were evaluated under same set of conditions. The lines which showed susceptibility at seedling and resistance at adult plant stage were categorized as Adult plant resistant lines. Detailed information of APR for two wheat rusts is presented in Table 10 and 11.

None of the lines showed appreciable APR to both leaf and stripe rusts. DBW187 possessed APR to all the three pts. of stripe rust and pt. 77-5 of leaf rust. Likewise, HD3086 conferred APR to stripe rust and pt.104-2 of leaf rust whereas HD3332 to stripe rust and pts. 77-5 and 77-9 of leaf rust.

Fifty-eight lines exhibited APR to different pts. of *P. striiformis*. Among these 12 lines viz. AKDW 2997-16(d) (C), DBW187(I) (C), DBW333, DDW47(d)(I), HD3086 (C), HD3249(I) (C), HD3332, HI8805(d)(I) (C), HI8818(d), MACS3949(d) (C), UAS428(d) (C) and UAS446(d) (C) could confer APR to three major pathotypes of *P. striiformis* in India. Fourteen lines conferred APR to two of the three pts. Thirty-two other lines possessed APR to 110S119 (Table 10).

Table 10. Race specific adult plant resistance (APR) in advanced wheat material to pathotypes of yellow rust pathogen (2019-20)

APR to Pathotype	No. of lines	Detail of lines
238S119, 110S119 and 46S119	12	AKDW 2997-16(d) (C), DBW187(I) (C), DBW333, DDW47(d)(I), HD3086 (C), HD3249(I) (C), HD3332, HI8805(d)(I) (C), HI8818(d), MACS3949(d) (C), UAS428(d) (C), UAS446(d) (C)
238S119, and 110S119	11	DBW291, DBW296, DBW332, HI1612 (C), HPW 349 (C), HPW 474, HS 562 (C), JAUW672, PBW811, WH1124 (C), WH1270
110S119, and 46S119	3	DBW328, HI 8823(d), MPO1357(d)
110S119	32	DBW173 (C), DBW252(I) (C), DBW303 *, DBW327, DBW331, DDW48(d)Q*, HD3298 *, HI8627(d), HS679, K1317, (C), MACS5055,

		MACS6222 (C), MP1358, MP1361, MP3288, PBW644 (C), PBW803, PBW804, PBW812, PBW840 (M), TAW155, UAS 472(d), UAS466(d)(I), UAS472(d), UP 3069, UP3033, VL 2036, VL 3024, VL 907 (C), WH1080 (C), WH1142 (C), WH1252, WHD964(d)
Total	**58**	

Fifty-seven lines of AVT (2019-20) conferred APR to one or more pathotypes of *P. triticina*. Nine lines (HD3378, HI1605, JAUW672, K1006, K1317, PBW811, UP3069, WH1080 and WH1252) showed adult plant resistance to three pts tested. Eighteen lines possessed APR to 2 pathotypes whereas 30 other lines supported APR to one or other pathotype (Table 11).

Table 11. Race specific adult plant resistance (APR) in advanced wheat material to pathotypes of brown rust pathogen (2019-20)

Pathotypes	No. of lines	Wheat Lines
77-5, 77-9 and 104-2	9	HD3378, HI1605, JAUW672, K1006, K1317, PBW811, UP3069, WH1080, WH1252
77-5, 77-9	9	DBW88, DBW327, HD3059, HD3332, HD3349, HD3377, HPW349, NIAW3170, VL892, WH1270
77-9, 104-2	3	HD2733, HS490, HS562, MP3336
77-5, 104-2	6	DBW296, HS668, HS679, HS681, PBW644, PBW804
77-5	13	DBW110, DBW252, DBW291, GW322, HD2932, HD3334, HI1612, HI1628, RAJ4083, TAW155, WH1021, WH1105, WH1124
77-9	5	DBW173, DBW187, DBW222, HS680, VL907
104-2	12	DBW290, HD3043, HD3086, HD3331, HD3298, HI8823, HPW474, MPO1357, UAS472, VL2036, WH1142, WHD964
Total	**57**	

5. Rust resistance in EBDSN and NBDSN lines at seedling stage

All the NBDSN and EBDSN lines were screened against the different pathotypes of three rusts of barley under precise conditions of temperature and light. Wherever needed, confirmatory and selected testing was also undertaken. These lines were evaluated against seven pathotypes of *P. striiformis hordei* (57, 24, M, G, Q, 6S0 and 7S0), five pathotypes of *P. graminis tritici* (11, 21A-2, 40A, 117-6 and 122), and 4 pts as well as mixture of pts. of *P. hordei* (H1, H2, H4, H5 and Mix). None of the

NBDSN and EBDSN entries was resistant to all the tested pathotypes of Pst, Pt and Pgt. The detailed report is presented below.

Rust resistance in NBDSN lines

A total 129 lines of NBDSN were evaluated against the different pathotypes of *Puccinia* spp on barley. None of the lines was resistant to all the rusts of barley. Twelve lines were resistant both to leaf and stripe rusts, one to stem and stripe rusts whereas 4 to leaf and stem rusts. In addition, 16 lines were resistant to stripe, 2 to stem and 22 to leaf rust only (Table 12).

Table 12. Seedling resistance of NBDSN entries to the pathotype of three rusts of barley 2019-20.

Rusts	No. of entries	Details of Entries
Leaf and stripe	12	BHS478, BHS481, BHS482, HBL865, HBL867, HBL868, PL908, RD3015, RD3016, RD3019, RD3021, HBL113(C)
Stem and stripe	1	DWRB182
Leaf and stem	4	DWRB197, KB1848, PL925, VLB169
Stripe	16	BH1030, DWRB213, HUB69, KB1817, KB1822, KB1830, PL906, PL911, RD2994, UPB1083, UPB1088, DWRB137(C), RD2552(C), RD2794(C), RD2899(C), RD2907(C)
Stem	2	DWRB212, PL915
Leaf	22	BHS479, BHS480, DWRB204, DWRB209, HUB273, KB1843, NDB1738, PL916, PL918, PL919, PL920, RD3011, RD3013, RD3022, UPB1080, UPB1085, UPB1086, VLB165, VLB166, VLB168, BHS400(C), VLB118(C)
Total	**57**	

Rust resistance in EBDSN lines

Forty-four lines were evaluated for resistance to three rusts by using all the virulent and predominant pathotype of each. Resistance to all the rusts was not found in any line. However, 9 lines were resistant to leaf and stripe rusts, 1 to stem and stripe rusts, 2 to leaf and stem rusts. Resistance to individual rust was observed in 19 lines. Of these 10 lines showed resistance to stripe, one to stem and 8 to leaf rust only (Table 13).

Table 13. Seedling resistance of EBDSN entries to the pathotype of three rusts of barley 2019-20.

Rusts	No. of entries	Details of Entries
Leaf and stripe	9	HBL113, HBL845, HBL863, PL908, PL2999, PL3000, PL3002, PL3003, PL3004
Stem and stripe	1	DWRB182
Leaf and stem	2	DWRB197, UPB1078
Stripe	10	BK1714, DWRB137, HBL848, PL906, PL909, PL2899, PL2980, PL2981, PL2994, PL3005
Stem	1	PL3010
leaf	8	BK1719(LB), DWRB184, HBL851, KB1633, KB1757, PL3009(LB), VLB130, VLB164
Total	**31**	

6. Screening of wheat and barley lines for rust resistance genes using molecular markers

Lr68 in Indian wheat material

Recently released wheat varieties were screened for presence of different leaf, stem and stripe rust resistance genes using molecular markers linked to those genes. *Lr68/Ltn4*, a slow ruster gene, is known to interact with other *Lr* genes to contribute for durable rust resistance. *Lr68* linked simple sequence repeat marker (CsGS-STS-*Lr68*) was used to screen 102 wheat lines which included most of the wheat varieties identified during the last few years (Fig. 1).

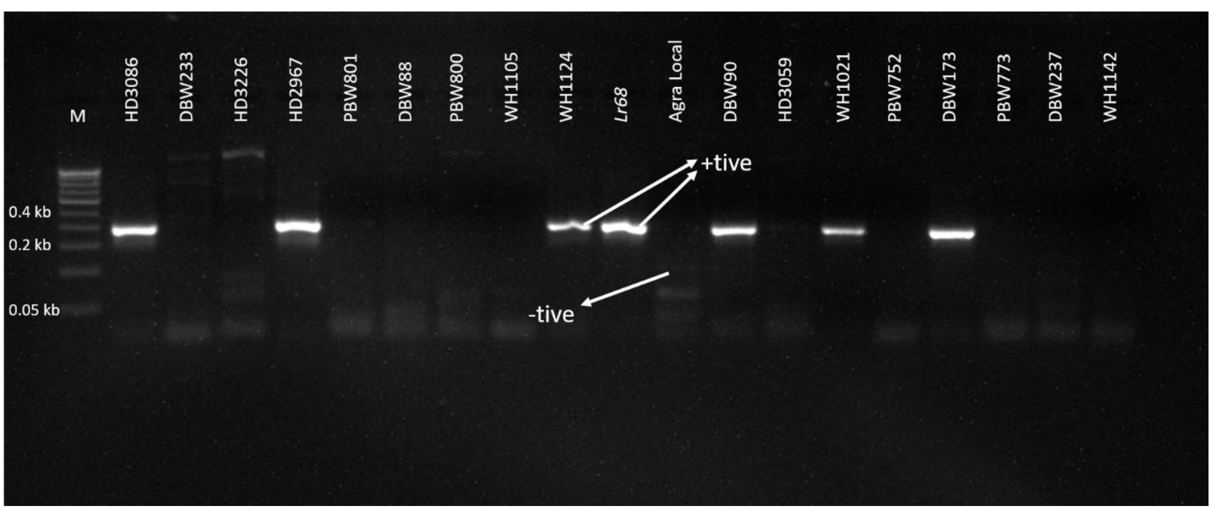

Fig. 1. Gel photograph showing the presence of *Lr68* in recently released wheat cultivars

Thirty four of these 102 lines showed the presence of *Lr68* (33.3% lines). This may be one of the interacting *Lr* genes in wheat which confers adult plant resistance to leaf rust in India.

7. Genetics of rust resistance and developing rust resistant genetic stocks

Generation advancement of breeding populations

Generation advancement of more than 500 wheat lines belonging to 4 breeding populations was done. Some of these populations were phenotyped for leaf, stripe and stem rust resistance at seedling stage against different pathotypes. About 15 new crosses for development of resistant varieties, genetic stocks or designation of new genes in durum and aestivum wheat lines was also attempted.

Evaluation of advanced breeding lines against yellow and brown rust

(Hanif Khan, ICAR-Indian Institute of Wheat and Barley Research Karnal, Haryana)

A total of 152 advanced breeding lines of bread wheat were evaluated for seedling resistance against prevalent and most virulent pathotypes of yellow and brown rusts. These wheat lines developed at IIWBR, Karnal are targeted for the varietal development for North Western Plain Zone where resistance against yellow and brown rust are very desirable traits. Out of 152 lines nineteen lines were resistant against all the six (238S119, T, 110S119, 110S84, 78S84 AND 46S119) pathotypes of yellow rust pathotypes. In case of brown rust a total of 32 lines showed resistance against all the four pathotypes (12-5, 77-5, 77-9, 104-2). The Table 14 shows the seedling resistance data of the lines identified with superior performance for grain yield and adult plant resistance.

Table 14. Seedling resistance data of elite bread wheat lines against prominent pathotypes of yellow and brown rusts

Genotype	Score against yellow rust pathotypes						Score against Brown rust pathotypes			
	238S119	T	110S119	110S84	78S84	46S119	12-5	77-5	77-9	104-2
RWP1001#	0;	0;	0;	0;	0;	0;	0;	0;	0;	0;
RWP1003#	0;	0;	0;	0;	0;	0;	0;	0;	0;	0;
RWP1005!	0;	0;	0;	0;	0;	0;	;-	0;	33+	;12

RWP1018#*	0;	0;	0;	0;	;-	0;	;-	0;	;-	0;
RWP1021#*	0;	0;	0;	0;	0;	0;	;-	0;	0;	0;
RWP1026#	0;	0;	0;	0;	0;	0;	;	3	;-	0;
RWP1027#	0;	0;	0;	0;	0;	0;	;1	0;	;-	0;
RWP1028#	0;	0;	0;	0;	0;	0;	;-	1	;-	;-
RWP1098	0;	0;	0;	0;	;-	0;	;1	33+	12	0;
RWP1106	3	3+	3+	0;	;	3+	0;	2+	2+	0;
RWP1007	0;	3	3+	0;	;	3	0;	2+	2+	2-
RWP1112	3+	0;	3	0;	;	3+	0;	1+	33+	;-
RWP1115	0;	3+	3	0;	0;	3+	;1	2	;1	0;
RWP1127*	3	0;	3+	3+	3+	3	;-	;-	0;	0;
RWP1136*	3+	3-	3+	0;	;	3+	;-	33+	3	;-
HD 3086 (C)	3+	3+	3+	3	2-	3+	;1+	3+	33+	33+
DBW 187 (C)	3+	3+	3+	3	;	3+	;	;1+	3+	;1
DBW90 (C)	3+	3+	3+	3-	2-	3+	;1+	3+	3+	3+
WH1142 (C)	3+	0;	3+	3	2-	3+	;	3+	1+	33+

#Presence of *Yr15* confirmed through molecular marker

! Presence of *Yr10* confirmed through molecular marker

*Presence of *Sr2* postulated based by micro-flecking

8. Genetic variability in *Puccinia* spp.

P. striiformis

For a better understanding of the genetic diversity, we designed 89 pairs of novel SSR primers from the DNA sequence of pathotype 46S119 and screened on 11 pathotypes. Twenty-four of these primers were polymorphic. A total of 69 alleles were detected across the loci with an average of 2.87 alleles per locus. Principal component analysis (*PCA*) revealed 55.53% variability among the *Pst* pathotypes. Polymorphic information content (*PIC*) value was in the range from 0.28 to 0.68, with a mean of 0.47. Expected heterozygosity was in the 0.34 to 0.73 range, with a mean of 0.56. Generated information will potentially help in rust resistance breeding and deployment of resistant cultivars in yellow rust-prone areas. Moreover, new SSR markers with a considerable level of polymorphism will be beneficial in distinguishing the *Pst* isolates/pathotypes at both national and international levels.

P. triticina

Five new pathotypes of *P. triticina* detected from Northeast India, Nepal and Bangladesh were studied in detail and the sources of resistance to these reported. Pathotypes 20-1, 49, 52-3 were identified from India, 162-5 from Nepal and 10-1 from

Bangladesh. Based on 25 pairs of SSR primers, these pathotypes were found distinct and broadly categorized in to two groups. Seventy-one lines, including 21 resistant to all the pathotypes, were identified that conferred resistance to these five new pathotypes. The detailed studies on these pathotypes, including distinguishing features, DNA marker based phylogenetic relationships, avirulence/virulence structure and sources of resistance were conducted.

P. graminis tritici

Molecular variability studies among the twenty-nine black rust pathotypes was carried out using selected *P. graminis tritici* specific SSR markers. Among the 30 black rust specific SSR markers, twenty were found to be polymorphic to selected pathotypes of *P. graminis tritici*. The polymorphic primers were further tested against all the black rust pathotypes. The PCR product was resolved in 3% Super MT4 Agarose (Life Technologies) instead of normal agarose, which in earlier attempts was not able to resolve the DNA bands properly. Some of the primers clearly differentiate black rust pathotypes (Fig. 2). Further analysis of the SSR genotypes is being carried out, which is expected to deliver good molecular genotype grouping of the Indian repository of black rust pathotypes.

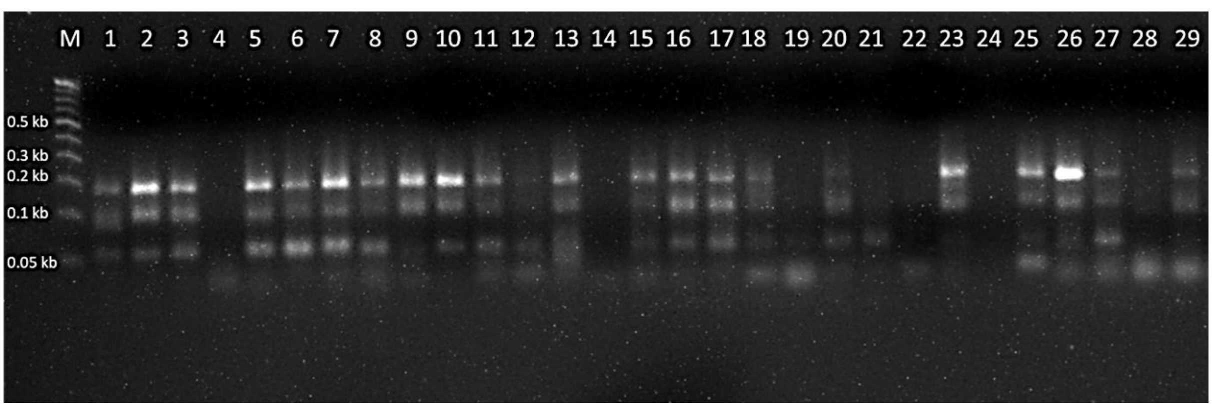

Fig 2. Allelic pattern among *Puccinia graminis tritici* amplified by SSR primer SSR-P TATC-40. PCR products were separated in 3 % Super MT4 Agarose gels. (M: 100 bp Ladder, 1 to 29 amplification pattern in pathotypes 11, 11A, 14, 15-1, 21, 21-1, 21A-2, 24A, 34-1, 40, 40A, 40-1, 40-2, 40-3, 42, 42B, 117, 117A, 117A-1, 117-1, 117-2, 117-3, 117-4, 117-5, 117-6, 122, 184, 184-1 and 295)

9. Maintenance and supply of nucleus inoculum of pathotypes of wheat and barley rust pathogens

A collection of more than 120 pathotypes of different rust pathogens of wheat, barley, oat and linseed were maintained in live culture as well as cryo-preserved. It has become difficult to maintain live cultures of more than 150 pathotypes of different rusts. Therefore, strategically less important pathotypes have been discontinued and sufficient inocula of those pathotypes have been cryopreserved for use in future. For the smooth conduct of wheat and barley rust research, nucleus/bulk inocula of different pathotypes of wheat and barley rust pathogens was supplied to more than 45 scientists/centers under public and private sector across India (Table 15).

Table 15. Details of rust inocula and seed supplied during the period.

Name	Affiliation
Ajay Agarwal	IGKV, Raipur, Chhattisgarh
Akhilesh Singh	CSKHPKV, Dhaulkan, Sirmour, HP
BC Game	ARS, Niphad, Maharashtra
CN Mishra	IIWBR, Karnal, Haryana
Deepshikha	GBPUAT, Pantnagar, Uttarakhand
DP Walia	IARI, Tutikandi, HP
G Vishwakarma	BARC, Mumbai, Maharashtra
GM Hegde	UAS, Dharwad, Karnataka
Hanif Khan	ICAR-IIWBR, Karnal, Haryana
IB Kapadia	JAU, Junagarh, Gujarat
Jaspal Kaur	PAU, Ludhiana, Punjab
JB Khan	CSAUAT Kanpur, UP
JP Jaiswal	GBPUAT, Pantnagar, Uttarakhand
KH Dhabi	JAU, Junagarh, Gujarat
KK Mishra	ICAR-VPKAS, Almora, Uttarakhand
KK Mishra	ARS, JNKVV, Powarkheda, Madhya Pradesh
Laxmi Kant	ICAR-VPKAS, Almora, Uttarakhand
LNU Harikrishna	IARI, Pusa, New Delhi
Lokendra Singh	ICAR-IIWBR, Karnal, Haryana
Madhu Patial	RS, ICAR-IARI, Shimla, Himachal Pradesh
MK Pandey	SKUAST, Jammu, J&K
Monika Garg	NABI, Mohali, Punjab
Neelu Jain	ICAR-IARI, New Delhi
NK Shrestha	ICAR-CSSRI, Karnal, Haryana

Pradeep Sharma	ICAR-IIWBR, Karnal, Haryana
Prakasha TL	ICAR-IARI, RS, Indore, MP
PS Shekhawat	RARI, Durgapura, Jaipur, Rajasthan
Rajbir Yadav	IARI, Pusa New Delhi
Rajender Singh Beniwal	CCSHAU, Hisar, Haryana
Sachin Upamanyu	CSKHPKV, Malan, HP
Sandeep Kumar	ICAR-NBPGR, Delhi
Sangeeta Gupta	ICAR-IARI, New Delhi
Satinder Kaur	PAU, Ludhiana, Punjab
SI Patel/Premawati	SDAU, Vizapur, Gujarat
SK Jha	ICAR-IARI, New Delhi
SP Singh	NDAU, Faizabad, UP
SS Vaish	BHU, Banaras, UP
Sudheer Kumar	ICAR-IIWBR, Karnal, Haryana
Sudhir Navathe	Agharkar Research Institute, Pune, Maharashtra
TK Nabte	RWRS, Mahabaleshwar, Maharashtra
Uttam Kumar	BISA, Ludhiana
Vaibhav Singh	ICAR-IARI, New Delhi
Vijay Rana	CSKHPKV, Malan, HP
Vishal Gupta	ICAR-IIWBR, Karnal
VK Sharma	HPKV, Akrot, Una, Himachal Pradesh

10. Wheat Disease Monitoring Nurseries

Wheat disease monitoring nursery was planted at 37 strategic locations evenly distributed throughout India. Data were received from all the locations except for 5. Yellow rust was noticed at all the locations of NHZ and NWPZ except IIWBR, RS, Shimla. It was not reported from any other zones including NEPZ and SHZ. More than 60S severity of yellow rust was reported from all the locations of NHZ and NWPZ except Tutikandi and Abohar where maximum yellow rust severity was 40S on Agra local, Lal Bahadur & WH147 (Tutukandi) and Lal Bahadur (Abohar). At least nine entries of WDMN had more than 40S severity at Almora, Bajaura, Akrot, Dalang Maidan, Khudwani, Dhaulakuan, Ropar, Gurdaspur, Langroya, Ludhiana and Pantnagar. Agra Local, Kharchia Mutant and WH147 had 100S yellow rust severity at Hisar.

Brown rust was reported from ten locations of NHZ and NWPZ *viz*. Almora and Pantnagar in Uttarakhand, Akrot and Flowerdale in Himachal Pradesh, Kathua and Jammu (Jammu), Hisar (Haryana), Langroya, Ludhiana and Abohar in Punjab. It was reported from all the locations of NEPZ except Ranchi. In central zone brown rust appeared at Raipur, Vijapur, Indore and Powerkheda and in PZ and SHZ at Dharwad, Niphad and Pune and Wellington. At Indore (CA) brown rust appeared only on Agra Local, Lal Bahadur and C-306 and other entries were brown rust free

Of the 32 locations of WDMNs, black rust was observed only at Gurdaspur in NWPZ, Powerkheda in CZ, Pune, Niphad and Dharwad in PZ and Wellington in SHZ. All the entries of WDMN were black rust free in NHZ and NEPZ. Leaf blight was reported from WDMNs planted at Almora, Kathua, Jammu (Udhaywalla), Sabaur, Ranchi, Kanpur, Varanasi, Raipur and Niphad. Powdery mildew was observed only at Almora, Akrot, Kathua, Jammu and Dhaulakuan. Wheat loose smut was reported only from Sabour.

SAARC wheat disease monitoring nursery was planted at 28 locations in India, Bangladesh, Bhutan, Nepal and Pakistan. Data were received from all the locations in India whereas, it is still awaited from the locations in other countries.

11. Visitors and News

a. Visitors

- Dr. Rajinder Singh Chauhan, Dean, Research & Consultancy, Bennett University, Greater Noida, Uttar Pradesh, India visited the station on 18^{th} March, 2020.

b. Training/conferences/Workshop/Meeting attended

- Drs. S. C. Bhardwaj and Pramod Prasad attended 7th International Conference on Phytopathology in Achieving UN Sustainable Development Goals organized by Indian Phytopathological Society at ICAR-Indian Agricultural Research Institute, New Delhi, India during January 16 - 20, 2020.

c. Joining/transfer/superannuation

- Dr. Charu Lata Sharma (Scientist, Plant Biotechnology) and Mrs. Sneha Adhikari (Scientist, Plant Breeding) furnished their joining letter on 4^{th} April 2020 by electronic mail.

d. Awards

- Sh. Bhoop Ram received Institute's best worker award in skilled supporting staff category for the year 2018.

e. Extension Activities

- Telephonic advisory about improved farming technology and disease, insect-pest management in crops was provided to the farmers in the five adopted villages in Solan District of Himachal Pradesh under prime minister's Mera Gaon Mera Gaurav scheme.

f. Activities under Swachh Bharat Abhiyan

- As part of the Swachh Bharat Abhiyan, swachata abhiyan was organized at the station. All the staff of the station including research fellows and contractual staff contributed in the abhiyan and collected plastics and other litter around the office and roads.

Annexure I

Updated Constitution of differential sets- 0, A and B for the binomial designation of pathotypes of wheat rust pathogens

Set-0	Set-A	Set- B
Brown rust (*Puccinia triticina*)		
IWP 94	*Lr14a*	Loros (*Lr2c*)
Kharchia Mutant	*Lr24*	Webster (*Lr2a*)
Raj 3765	*Lr18*	Democrat (*Lr3*)
PBW 343	*Lr13*	Thew (*Lr20*)
UP 2338	*Lr17*	Malakoff (*Lr1*)
K 8804	*Lr15*	Benno (*Lr26*)
Raj 1555	*Lr10*	HP 1633 (*Lr9*+)
HD 2189	*Lr19*	
Agra Local	*Lr28*	
Black rust (*Puccinia graminis tritici*)		
Sr24	*Sr13*	Marquis (*Sr7b*+)
NI 5439	*Sr9b*	Einkorn (*Sr21*)
Sr25	*Sr11*	Kota (*Sr28*+)
DWR 195	*Sr28*	Reliance (*Sr5*+)
HD 2189	*Sr8b*	Charter (*Sr11*+)
Lok 1	*Sr9e*	Khapli (*Sr7a, Sr13, Sr14*)
HI 1077	*Sr30*	Tc*6/*Sr31/Lr26*(*Yr9*)
Barley Local	*Sr37*	
Agra Local		
Yellow rust (*Puccinia striiformis*)		
WH147	Chinese 166 (*Yr*1)	Hybrid 46 (*Yr4*)
HS507	Lee (*Yr*7)	Heines VII (*Yr*2+)
Hobbit	Heines Kolben (*Yr*6)	Compair (*Yr*8)
PBW752	Vilmorin 23(*Yr*3)	*T. spelta album* (*Yr*5)
PBW757	Moro (*Yr*10)	Tc*6/*Lr*26(*Yr*9)
PBW343	StrubesDickkopf	Sonalika (*Yr*2+)
HS240	Suwon92 X Omar	Kalyansona*Yr*2(KS)
Anza	Riebesel47/51(*Yr*9+)	*Yr24*/3AvS
A-9-30-1		*Yr15*/6AvS
Bilara-2 (Barley)		*Yrsp*/6AvS