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Preface

As a national strategy under the overall umbrella of Indian Council of Agricultural Research, Indian Institute of Wheat and Barley Research (IIWBR) is coordinating All India Wheat and Barley Improvement Project through which rust pathotypes are being monitored, strategically resistance genes are incorporated with major emphasis on adult plant resistance (APR) and slow rusting. Multilocation evaluation of advanced wheat lines and identification of promising varieties for release to the farmers and their notification is carried out to deploy cultivars with diverse genes in the country for keeping the rusts at their lowest ebb. A constant vigil on rust is being kept in the entire country in coordination with state agricultural universities and other centres of ICAR. Rust pathotypes have been maintained at IIWBR Regional Research Station, Flowerdale, Shimla. However, threat of rusts is looming large as new pathotypes are appearing. In 2001, new yellow rust pathotype 78S84 virulent on PBW 343 (*Yr27* virulence) was detected whose inoculum got built up slowly and slowly due to its cultivation over large areas. The variety was high yielding and occupied 6-9 million hectares area in different years. It became popular amongst farmers in the hilly regions as well. Since 2006-07, the stripe rust is occurring in high intensity in one or the other parts of NHZ and NWPZ. Emphasis was laid for growing rust resistant wheat varieties such as PBW 550, DBW 17 and WH 542 of bread wheat in disease prone areas.

Due to congenial weather for stripe rust, two pathotypes, 78S84 (*Yr 27* virulence on PBW 343) and 46S119 (*Yr 9* virulence) dominated during 2010-11 crop season and most of the varieties grown in North Western Plain Zone became susceptible. During 2011-12, stripe rust incidence was less as compared to 2010-11 and stripe rust pathotype 46S119 dominated. To create genetic diversity at farmers' field, several stripe rust resistant varieties viz., HD 2967, WH 1105, HD 3086, DBW 88, HD 3059, WH 1021, WH 1080, HD 3043, DBW 71, DBW 90, HS 507, HPW 349 and HS 542 were released. During 2014-15, though the disease was detected in mid December of 2014, conditions for stripe rust remained favourable, however, the disease did not spread to larger areas and losses were avoided. During 2014-15, five new stripe rust pathotypes were recorded on account of migration and mutation. But timely action taken by IIWBR, SAUs', DAC and State Departments helped in averting epidemics and India harvested record production. This bulletin is an effort to put on record the historical and recent account of stripe rust prevalence, the strategic initiatives undertaken in India to meet the challenge of containing the disease under the umbrella of Indian Council of Agricultural Research coordinated by IIWBR involving State Agricultural Universities, Central and State Govt. functionaries of Department of Agriculture. It is a success story that India had record harvest during 2014 producing 95.91 mt when some of the countries had severe stripe rust epidemic during the preceding years.

Authors

An Update on Wheat Stripe Rust Management in India-A Success Story

Introduction

Overall India is the second largest producer of wheat after China. Wheat is the next most important food crop in the country following rice, both in area, production and consumption. Wheat growing regions in India represent a diverse agro-climatic conditions. The country has witnessed an increase in wheat area from 10 million hectares in early sixties to around 30.37 million hectares in 2014-15. The major wheat growing states of India are Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Rajasthan and Bihar. These states account for about 90% of India's total wheat produce. The success story of enhanced wheat production during last 40-45 years by keeping the rusts at its lowest ebb demonstrates the strength of not only of the consolidated efforts of the technology developed by the scientists across the country but the government's policies for making them adaptable by the farmers through different countrywide programmes. The era of cultivation of semi-dwarf wheat which began in 1960's, ushered a phenomenal success as these genotypes along with spurt in inputs revolutionized the wheat production in the following years, leading to "Green Revolution". The wheat production in India, ever since has increased many folds from 6.4 mt in 1950 to 95.91 mt during 2013-14 with productivity to the tune of 3.07 t/ha. Sustaining this level of productivity is a big challenge and efforts are on to break the yield barriers.

A host of biotic and abiotic stresses affect wheat crop leading to huge losses in yield. Since wheat is grown in different agro climatic conditions in our country, the constraints to its production vary from one zone to other. Biotic stresses are the main constraints in wheat production worldwide. The black or stem rust (*Puccinia graminis* Pers. f. sp. *tritici* Erikss. & Henn) is important in warmer areas whereas the brown or leaf rust (*P. triticina* Eriks.) in the entire country and the yellow or stripe rust (*P. striiformis* Westend.) in cooler areas.

Wheat rust epidemics and economic losses in India

In India, epidemics due to stripe rust have occurred in one or the other region of north hills and north western plains about once in every 10 years. Losses of 100% can occur in fields of highly susceptible cultivars and the pathogen has a narrow spectrum of virulence in these zone on wheat (Saari and Prescott,1985). It assumes great economic significance, especially in the parts of areas with cool and wet environmental conditions spread over 10 million hectares. It has been stated that the rust caused huge losses during 1904-05, in parts of Punjab due to damp weather and lack of sunshine. Between 1967 and 1974, brown and yellow rusts occurred every year, but only twice caused appreciable damage through the isolated epidemics that occurred in some pockets of western Uttar Pradesh during 1971-72. A pandemic of the same two rusts occurred during 1972-73 in western Uttar Pradesh, Haryana and Punjab (Joshi, 1975; Nagarajan and Joshi, 1975).

Cultivation of resistant varieties is the most effective, eco-friendly and economically viable method of managing wheat stripe rust. However, rust resistant cultivars of wheat become susceptible due to origin

of new variations in stripe rust pathogen. A rust resistant cultivar generally becomes susceptible in about five years (Sawhney, 1995). Chemicals are generally avoided and deployed under emergency situations only to curtail the initial inoculum. Varietal development with diverse resistance and deployment is in place in India. But rust virulences also keep pace with this change and the varieties which are grown over large areas gradually succumb to rusts as new virulence appear. In spite of climate change as reflected by fluctuations in weather conditions and occurrence of stripe rust in high proportions in parts of India an increasing trend in wheat production was recorded for 6 years in a row from 2006 to 2015 with some decline during 2012-2013 and 2014-15 due to higher minimum temperature and heavy rainfall in a very short spell of time resulting in water logging.

Tracking rusts

The importance of crop health monitoring in Indian wheat programme was realized as early as 1920's and random surveys were conducted by Prof. K.C. Mehta and colleagues. From time to time there was integration of mobile surveys, trap nurseries, use of satellite for disease survey and evaluation of spore dissemination, infra-red image (s), analysis of rain samples for uredospores to monitor the disease situation. In addition mobile surveys were undertaken at various crop growth stages, along the specific routes. These roving or mobile surveys also helped in keeping a vigil on the entry of a new pest or pathotype. A very good example is the detection of a new virulence (*Yr*9 virulence) of stripe rust in 1996 from the bordering areas of Punjab and identification of stripe rust resistant germplasm within two months of its confirmation. Subsequent surveys carried out through mobile units and trap nurseries generated considerable information on the appearance and spread of rusts in different parts of the country became an integral component of wheat improvement. During 1967-68 under the All India Co-ordinated Wheat Improvement Project (AICWIP), monitoring of diseases of wheat crop was systematically introduced in all wheat growing states to know the prevalence, spread of wheat diseases and performance of cultivated wheat varieties to rusts. Co-operating scientists in different states monitored the wheat crop at 15 days interval starting from either December end or after the crop is more than 45 days of maturity. Each state has different agro-climatic regions and the extensive and intensive monitoring was done in disease prone areas, however, other areas were also monitored on alternate trips. A team of 2-3 scientists at fortnightly intervals moved by car in different directions in a state and halted at a distance of 30 to 50 Kms to monitor 2-4 wheat fields on both sides of the road. In case there are 2-3 patches of the disease in a range of 100-200mts having traces to 40S it was considered to be of limited occurrence but if there are >5 such patches having infection varying from traces to 80S it was considered spreading and then the adjoining fields were monitored intensely more so if the field was grown with a susceptible variety. Sometimes the spread could be visualized just standing outside the fields such fields were considered to be severely infested where farmers are immediately apprised of the fact that if the crop was not sprayed losses could occur. The losses may vary from <1 to 100% depending upon the varietal susceptibility, stage at which infection occurs and the severity of infection on flag leaf up to grain formation stages. Many a times under severe situations of the rust infection, the sporulation occured on glumes and pericarp of the grain. Under any situation of rust prevalence from, mild to severe form scientists of Agricultural Universities, KVK staff and

officers of Department of Agriculture were contacted for awareness campaigns to apprise the farmers of rust detection and spraying the crop with fungicide (s) and also making it available timely through Government agencies.

Besides, mobile surveys another strategy had been planting of Wheat Disease Trap Plot Nursery (TPN). To specify the exact purpose, the nursery was later on designated as Wheat Disease Monitoring Nursery (WDMN). The nursery had become an integral part of the Crop Protection programme and has assumed so much significance that it was regularly planted at various strategic locations and constant watch was kept on the appearance and spread of wheat diseases both in regular as well as off-season crop. Such nurseries usually contained varieties or entries with known genetic constitution so that the occurrence or appearance of a new pathotype or pest could be identified. Under the AICWIP, the Wheat Disease Monitoring Nursery (WDMN/TPN) was planted at multi-locations including those all along the western border (Fig.1). At present, it was planted at more than 60 locations. Looking into the spurt of stripe rust in the last 5 years, more locations had been added during 2013-14 where stripe rust is noticed early and appeared regularly every year. It contained a common set comprising of 15 lines having popular varieties, resistant varieties, a susceptible variety and some resistant lines. In addition, five predominantly cultivated zone specific varieties were also part of this 20 lines nursery. It served as an important tool to know the wheat disease situation, progress and appearance of new variants or races on resistant materials. It also helped to keep a vigil on the occurrence of wheat diseases along the western border, especially for the stripe rust. Every year, the crop health was monitored and the field samples of the rusts were analyzed for their virulence (pathotype analysis). Distribution pattern of the rust virulences (pathotype) provided much-needed orientation for the wheat breeding programmes and executing the resistance-gene / varietal deployment.

Common set of varieties of wheat disease monitoring nursery

WL 711, HD 2329, Agra Local, HD 2160, Lal Bahadur, WL 1562, HW 2021(*Sr26/Sr24*), HD 2204, C 306, WH 147, HW 2008 (*Sr24/Lr24*), Kharchia mutant, HP 1633, DL 784-3 and RNB 1001.

Zone specific varieties

NWPZ: WH 1105, WH 542, PBW 343, DPW 621-50 and WH 896

NEPZ: K 8804, HD 2402, HP 1102, HUW 468 and NW 1014

CZ: HI 8381, DL 803-3, Lok -1, GW 273 and GW 322

PZ and SHZ: MACS 2496, Bijaga Yellow, HW 971, HD 2501 and HW 2022 (*Sr24/Lr24*)

NHZ and High Altitude Zone: HPW 349, VL892, HS 420, Sonalika, HS 507 and Barley Local

On the same pattern as that of WDMN / TPN, the wheat programme had formulated a Regional Wheat Disease Monitoring Nursery, called as SAARC Nursery for planting in Afghanistan, Bangladesh, India, Nepal and Pakistan in collaboration with CIMMYT, Kathmandu. This nursery was started in 1989-90 and first planted in 1990. It is composed of twenty varieties viz. Annapurna-1, WL 1562, HD 2204, PBW 343, HD 2687, HD 2189, HP 1633, RAJ 3765, PBW 373, Pak 81, Punjab 65, Chakwal 86, Faisalabad 85,

Inquilab 91, Faisalabad 83, Rawal 87, Kohsar, Bakhtawar 94, Gourab and susceptible check drawn from the member countries. This nursery was also constituted at regional research station, Shimla (IIWBR - ICAR) centre and since 2012-13 crop season, CIMMYT - Nepal also co-ordinated this activity. The disease appearance in the nursery provided an evidence of comparative wheat disease situation and virulences prevalent in the SAARC countries. The nursery was monitored by the co-operators of the respective location. These observations helped a breeder to re-cast the breeding strategy towards building resistance to the new or likely to emerge virulences before these (pathotypes or virulences) become a real threat.

Identification of new virulent pathotypes of *Puccinia striiformis* at initial stages

Cultivation of rust resistant varieties favour the selection of new virulent pathotypes and at times result in shift of virulence pattern. Since a pathotype has a slag period between its identification and reaching the epidemic level, therefore, new pathotypes are identified in the initial stages. By the time, a new / virulent pathotype can become epidemic, stripe rust resistant material is already in the pipeline. The pathotype identification and evaluation of germplasm at seedling and adult plant stages is undertaken at IIWBR, Regional Station, Flowerdale, Shimla.

A perusal of avirulence / virulence structure of Indian pathotypes shows that most of the new pathotypes which are now prevalent in Northern India have evolved locally or at the most in the bordering areas. The step wise change in different pathotypes of stripe rust in India is presented in Table 1. More virulent pathotypes got selected and resistant varieties / genes succumbed to the new pathotypes. Since rusts are airborne and can spread over long distances, therefore, threatening introduction of stripe rust pathotypes from the adjoining countries as well as inter-state movement always makes wheat crop in Northern India more prone to stripe rust. Hence, we have always advocated regional as well as international co-operation to combat this common enemy. Deploying diverse genes could be the best strategy to avoid epidemics / pendemics.

Table 1. Shift in wheat stripe rust pathogen during 1967 to 2001

Year	Cultivar	Pathotype	Virulence
1967	NP 846, Hyb 633, Lerma Rojo 64, Sonora 64	67S64(31), 70S4(A)	Avirulent on Kalyansona
1970	Kalyansona	66S-64-1(38A) 66S64(14A), 70S64 (20A)	Virulent on Kalyansona, avirulent on Sonalika
1967	Sonalika	-	Resistant to Kalyansona virulences
1982	-	47S102 (K)	Virulent to Sonalika, avirulent to CPAN 3004 and HS 240
1996	CPAN 3004, HS240	46S119	Virulent to CPAN 3004 and HS 240 Virulent to many *Yr9* lines and avirulent to PBW 343
2001	PBW343	78S84	Virulent to PBW 343

Not known

Locations of Wheat Disease Monitoring Nursery in India

Predominant pathotypes of wheat rusts in India are 38S102 (I) (Nilgiri hills) and 78S84, 46S119 (North Western India, North Hill Zone). Pathotype 46S119 was identified from Gurdaspur in 1996 whereas 78S84 was detected from Batala in 2001. Both these pathotypes did not occur in other areas of Himachal Pradesh and adjoining states for long (Table 2). Thirty two pathotypes identified since 1932 are being maintained at IIWBR, Regional Station, Flowerdale, Shimla.

Table 2. Comparative frequency of predominant pathotypes of *P. striiformis* in India

Year	46S119	78S84
1996	Identified from Gurdaspur, occurred in 31 samples from Punjab and Haryana	-
1997	Punjab 50% samples from adjoining H.P., Haryana and Rajasthan in 25% samples	-
1998	-do-	-
2000, 2001	45% samples of all areas except Kinnaur	Identified from Batala, Punjab
2005, 2011	45% samples	8 samples from Punjab in 2005 In 2011 in 46% samples
2012	53% samples	37% samples
2013	67% samples	25% samples

Not detected

New pathotpes of *Puccinia striiformis* detected in 2015 in India

During 2014-15, wheat rust population analyzed was found avirulent to *Yr 5, Yr10, Yr13, Yr14,Yr15, Yr26, YrSp* and*YrSk*. During 2015, 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 stripe rust pathotypes are progressive mutations in the existing pathotypes and are more aggressive. *Yr11, Yr12* and most probably *Yr24*, which used to be resistant to stripe rust in India, have been rendered susceptible.

Performance of SAARC wheat disease monitoring nursery in Pakistan and Afghanistan indicated differences in the flora of these countries when compared with that of India. Most of the lines supported moderate stripe rust in these countries, whereas in India, corresponding infection was more than 20S at most of the locations. Frequency of these pathotypes keeps on changing with the climatic conditions and type of variety. Pathotype 46S119, identified in 1996 remained predominant up to 2011 whereas later on 78S84 was more common (Table 2). With the replacement of PBW 343 proportion of 78S84 declined whereas 46S119 increased in frequency in 2014-15 (Fig. 1).

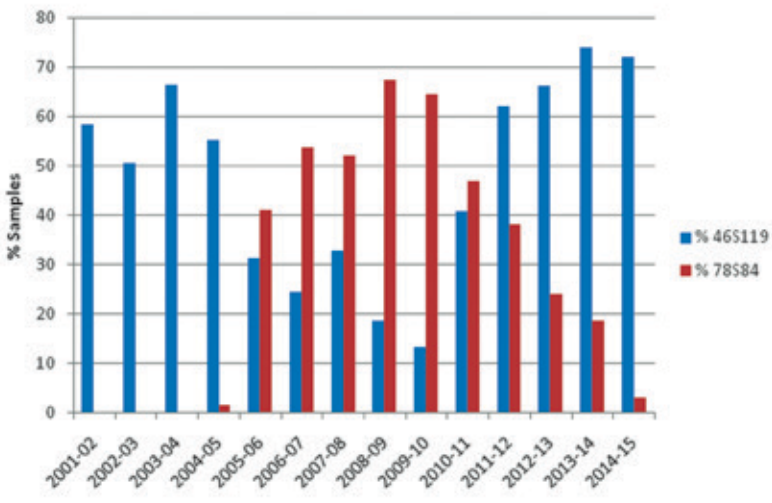


Fig. 1. Prevalence of stripe rust pathotypes during 2014-2015

Stripe rust resistance genes in Indian wheat material

Based on the gene matching technique, five *Yr* patterns *viz. Yr2, YrA, Yr9, Yr18* and *Yr27* have been identified in Indian wheat material. These resistance genes were present either singly or in various combinations. Some of the lines have been shown to possess APR or slow rusting also. 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 during 2014-15.

Stripe rust status (2000-2015)

Crop health was monitored thoroughly during the crop season as well during the off season. Major focus was on the occurrence of stripe rust as it was noticed in high proportions in some of the areas during 2006 in the last 7 years. The extensive surveys were conducted by the wheat crop protection scientists of different cooperating centres including IIWBR Karnal. Special teams of scientists were constituted every year during the All India Wheat Workers' Meets. Information on wheat crop health was disseminated through the "*Wheat Crop Health Newsletter*", which was issued on monthly basis during the crop season. The newsletter was also put on IIWBR website (http://www.dwr.in). Advisories for varietal deployment and protection technologies are issued to the farmers for stripe rust management as and when required.

In 2001, a new pathotype 78S84 of *P. striiformis* with virulence on PBW 343 (*Yr* 3, *Yr* 9, *Yr* 27 virulences) was detected whose inoculum got built up steadily due to the cultivation of PBW 343 over a large area (Prashar *et al*., 2007). The variety was high yielding and occupied 6-9 million hectares area in different years. It became popular amongst farmers in the hilly regions and eastern India as well. The stripe rust pathogen survives in Northern India and as a result of continuous growing of susceptible varieties in the major wheat belt of North Western Plain Zone (NWPZ), the inoculum built up also increased in the hilly areas. Since 2006-07, the stripe rust is occurring in high intensity in one or the other parts of North Hill Zone (NHZ) and NWPZ. Emphasis was laid for growing rust resistant wheat varieties such as PBW 550, DPW 621-50, WH1021, HD3043, WH 542 of bread wheat in disease prone areas of NWPZ whereas HS375, H490, HS507, VL892 and VL907 in NHZ. Due to congenial weather for stripe rust, two pathotypes, 78S84 (*Yr* 27 virulence on PBW 343) and 46S119 (*Yr* 9 virulence) were most prevalent during 2010-11 crop season and many of the varieties grown in North Western Plain Zone became susceptible. During 2010-11 due to congenial weather, stripe rust appeared in severe form in the plains of J & K , foot hills of Punjab and Himachal Pradesh, parts of Haryana and tarai region of Uttarakhand wherever susceptible varieties were grown. In Punjab, especially in the districts of Ropar, Nawan Shahar and Hoshiarpur, the disease was well spread over a large area on most of the varieties being grown by the farmers. In Haryana, the disease was severe in Yamuna belt. During 2011-12, stripe rust incidence was less as compared to 2010-11. But timely, coordinated efforts by IIWBR (ICAR), SAUs', DAC and State Agriculture Departments helped in averting the epidemics and India had a record harvest. An account of prevalence and spread of stripe rust during 2000-01 to 2014-15 is given in Tables 3-8.

Table 3. Stripe rust prevalence during 2000-01 to 2009-10 crop seasons

Year	Place	Varieties	Intensity
September 5, 2000	Dalang Maidan, Lahaul valley (HP)	PBW 343 in trap plot nursery	10S
3rd week of March, 2001	Batala (Punjab)	PBW 343 in farmers' fields	20S
Last week of March, 2001	Gurdaspur (Punjab)	PBW 343 in seed multiplication plot	TS-40S
January 21, 2002	Dhaulakuan, Paonta (HP)	Local variety in farmers' fields	Traces
Last week of February, 2002	Karnal (Haryana)	UP2338	Traces
March 15, 2002	Haryana: KVK Kaithal, RRS Uchani (Karnal), Pashina village of Panipat	UP 2338, HD 2329 and HD 2687	Traces - 20S
Last week of January, 2002	Pantnagar (Uttarakhand)	HUW 234	Traces
March 4, 2002	Mahal Kalan, Sangrur (Punjab)	HD 2329	5S
1st week of March, 2003	Ludhiana (Punjab)	WL 711, HD 2329 and HD 2687	5S
1st week of March, 2003	Kurukshetra (Haryana)	UP 2338	10S
Mid March, 2005	Kangra and Mandi (HP)	Sonalika, HS 240, VL 738 and UP 2338	40-60S
March 14, 2005	Haryana:In Karnal and adjoining districts (at village Mathana, Dist. Kurukshetra)	HD 2687	10S
Mid March, 2005	Yamunanagar (Haryana)	WH 711	40S
March, 2006	Haryana: Barwala (Hisar), Indri, Nilokheri (Karnal), Ladwa, Kheri Dablan (Kurukshetra), Kaul (Kaithal), Damla (Yamunanagar) and Samar Gopalpur (Rohtak)	UP 2338, HD 2687, C 306, PBW 373	TS-40S
April, 2006	HP: Sundernagar and Mandi	PBW 343	40S
January, 2007	Bhali (Uttarakhand)	Local variety	TS
March, 2007	Kangra, Una and Mandi (HP)	Susceptible wheat varieties	40-80S
March, 2007	Dhaulakuan, Paonta Valley of Himachal Pradesh	VL 616, Raj 3777, UP 2338, HS 420 and PBW 343	Moderate to severe incidence
March, 2007	Punjab and Haryana	PBW 343/ PBW 502 and unidentified varieties	5-20S

January 27, 2008	Bharapur near Dhaulakuan (HP)	Raj 3077	5S
March 3, 2008	Samrala, Mohali, Banur and Rajpura	Local variety	80S
March 7, 2008	Phillaur, Goraya, Jallandhar, Dasuya, Mukerian, Batala, Beas and in isolated pocket at village Kolian near Mukerian	Local variety	80S
March 7, 2008	Jeevanwal (Uttarakhand)	Local variety	Traces - 60S
March 7, 2008	Almora (Uttarakhand)	Agra Local	TS
Mid March, 2008	Village Tuker, Pehowa (Kurukshetra)	PBW 343 and PBW 502	60S
Mid March, 2008	Indora and Mand (river Beas basin), Kangra (HP)	PBW 343 and PBW 502	60-80S.
Mid February, 2009	Sundernagar and Una (HP)	HS 240, HS 295, PBW 343 and PBW 502	60-80S
Mid February, 2009	Nihalgarh (Paonta), Sirmour (HP)	HPW 211, HPW 184, HS 295 and WH 711	20S
Last week of February, 2009	Nihalgarh (Paonta), Sirmour (HP)	HS 240	40S
Last week of February, 2009	Haroli, Garget (Una)	PBW 343 and PBW 502	60S
January 7 – 9, 2009	Punjab: Banur (Patiala), Mianpur (Ropar), Girina Sahib and near Tanda (both in Hoshiarpur)	PBW 343	40S
January 7 – 9, 2009	Gadu Majra near Rajpura, Patiala	PBW 343	60-80S
January 7 – 9, 2009	Panjoli near Mianpur (Ropar)	PBW 343	10-20S
February 17, 2009	Hoshiarpur and Jallandhar districts enroute Phagwara, Rehanan Jattan, Attowal, Navin Bassi, Dadoha-Dholwala road, Chakk Gujran, Jallandhar, Chaheru and Phillaur and in certain pockets	PBW 343	80S
March 20-22, 2009	115 fields at 45 sites in Punjab along the foothills and international border	PBW 343	20S to 80S
March 20-22, 2009	Patiala and Sirhind showed a lesser incidence	PBW 343	20-40S
February 12, 2009	Neval, Karnal (Haryana)	PBW 343	40-60S
April 2-4, 2009	Karnal, Yamunanagar and Ambala (Haryana)	PBW 343, PBW 373, PBW 502, UP 2338 and HD 2329	TS-80S
2nd week of February, 2010	Ropar and Nawanshahar districts	PBW 343	TS

February 23, 2010	Akbarpura, near Malerkotla	PBW 343	TS
February 27, 2010	Ladhowal (Ludhiana)	PBW 502 (10S) and PBW 550	20MS
Mid March, 2010	Chamkor Saheb (Punjab)	WH 711	10S
March 15, 2010	Ladhowal (Punjab)	PBW 343, PBW 502, WH 711	10S
March 15, 2010	Ropar, Hoshiarpur and Gurdaspur districts (Punjab)	PBW 343, HD 2733	TS-30S
March 15, 2010	Fatehgarh Sahib (Punjab)	PBW 343	40S
Last week of March, 2010	Yamunanagar and Karnal districts (Haryana)	PBW 343	10S

Table 4. Stripe rust prevalence during 2010-11 crop season

Year	Place	Varieties	Intensity
HP			
February 6, 2011	Salani, Nahan	WH 147, PBW 343 and local cultivars	20-90S
2nd week of February, 2011	Paonta block (Villages Kolar and Surjapur)	WH 711	20S
2nd week of February, 2011	Parts of districts Kangra (Kangra, Shahpur and Dehra blocks), Mandi (Balh valley, Sarkaghat block), Bilaspur (Ghumarwin, Barthin blocks) and Una (Amb, Gagret blocks).	PBW 343, PBW 373, PBW 502, HS 240, HS 295, RAJ 3765, UP 2338, HS 420 and HPW 184	10-80S
February 21, 2011	Gularbhoj, Bairia Dulatpur, Premnagar, Gangapur, Sawai, Maheshpur, Jaitpur, Kannur, Shivpur, Jhankaal and Makhawara	PBW550 and DBW17 UP 2338, PBW 154, PBW 373, WH 147, UP262 and PBW343	5-20S
August, 2011	High altitude areas of Kinnaur, Lahaul and Spiti	Local Varieties	40S
Punjab			
2nd week December, 2010	Balachaur	PBW 343	10S
December 23, 2010	Ghoon, Shaheed Bhagat Singh Nagar	PBW 343	20S
December 11, 2010	Ghoon (Balachaur) and Chhidauri (on Garhshankar-Balachaur road)	DBW 17	5-10S
December 11, 2010	Munan Khurd of District Gurdaspur	-	60S

December 11, 2010	Kaler Khurd on Gurdaspur- Batala road.	-	TS
J & K			
January 2, 2011	State Agriculture Farm, Chinoor, Jammu	PBW 502	80S
January 2, 2011	Chatha	PBW 343, DBW 17 and PBW 502	20S
January 2, 2011	Marheen, Chhan Arorian, Ghagwal, Chanjval and Mathura check of Jammu	PBW 343, DBW 17 and PBW 502	TS-40S
Last week of February, 2011	Jammu, Samba, Kathua and Akhanoor areas.	PBW 343, PBW550, PBW 502 and DBW 17	60-100S
Last week of February, 2011	Jammu, Samba, Kathua and Akhanoor areas.	PBW175 and RSP561	30MS
Last week of February, 2011	Jammu, Samba, Kathua and Akhanoor areas.	RAJ 3077 and RAJ 3765	10S
Haryana			
February 4, 2011	Village Rasul Khurd in Karnal	DBW 17, PBW 550, PBW 343 and HD 2851	60S
February 28, 2011	Jhamba (Panipat)	DBW17 and HD 2851	60-80S
January 27, 2011	Mathana (Ladwa, Kurukshetra)	HD 2932, DBW17 and PBW 550	TS-40S
January 27, 2011	Ladwa-Radaur road, near Jasmeer Food Pvt. Ltd.	DBW 17	60-80S
January 27, 2011	At KVK Damla (Y. Nagar)	PBW 343	40-50S
January 27, 2011	Yamuna Nagar-Tajewala road	DBW 17	70-80S
January 27, 2011	Manakpur (Yamuna Nagar)	DBW 17	20-30S
January 27, 2011	Chhachrauli - Tajewala road at Tajewala village (Yamuna Nagar)	PBW 343	40-50S
February 28, 2011	Kanipla (Kurukshetra)	DBW 17	30S
February 28, 2011	KVK Ambala	PBW 343	TS-5S
February 28, 2011	Balana (Ambala)	PBW 343	10-20S
February 28, 2011	Pauri village (Ambala)	DBW 17	40-60S

February 28, 2011	Pehowa (Kuruksheetra) near Hariyali Kisan Bazar	PBW 343	TS-5S
February 28, 2011	Ismailabad (Kurukshetra)	DBW 17	60S
February 28, 2011	Jalsui and Jalbera (Kurukshetra)	PBW 343	10-30S
February 28, 2011	KVK Kaithal Farm	DBW 17	TS
February 28, 2011	Titram Mor (Kaithal)	PBW 343	TS

Strategic planning

There had been recurrence of stripe rust in some of the years and the situation demanded planning not only at the scientific level but also involved policy issues which could only be carried out through the department of agriculture and cooperation. During 2010-11, strategic plan was envisaged to limit its occurrence and spread of stripe rust in India. Major emphasis was on bringing in farmers'awareness in replacing susceptible varieties with resistant ones, early detection of the rust/initial foci of infection by regular monitoring after 40 days of planting and immediately spraying wheat with fungicides to limit its spread. Special cards were devised for the awareness to farmers and circulated in large numbers in all the affected areas. In high disease prone areas, TRAP nursery/advanced varieties trials were planted for early detection of stripe rust/identifying resistant varieties. Varietal development and deployment of new varieties is a regular feature in the country which was further strengthened and led to create genetic diversity at farmers' field through release and popularization of several stripe rust resistant varieties viz., HD 2967, WH 1105, HD 3086, DBW 88, HD 3059, WH 1021, WH 1080, HD 3043, DBW 71, DBW 90, HS 507, HPW 349 and HS 542.

Following action points were envisaged during 2011 for stripe rust management

- To continue monitoring wheat crop from December onwards at regular intervals of 15-20 days and initiate stripe rust management activities in disease prone areas in HP, J&K, Punjab, Haryana, Uttarakhand and UP by Agricultural Scientists, Extension specialists and Agricultural Officers working with state Department of Agriculture.
- Exploring the possibilities of use of remote sensing for early detection of infection foci in stripe rust affected states / to get a better picture of areas affected.
- Awareness campaigns to educate the farming community regarding identification and management of stripe rust through press, electronic media and literature in local languages of respective states prior to sowing of wheat crop (August – October) for choice of wheat varieties to be grown, to identify the disease symptoms, importance of time to time field visit by themselves for early detection of the disease, apprising them of primary focus of stripe rust infection, advising to avoid early sowing under shade / trees and management with emergency spray of recommended fungicides.

- To ensure planting of TRAP and SAARC nurseries in Kashmir, Jammu, Dalang Maidan, low hilly areas of HP, Punjab, Haryana, Uttarakhand by end of October and in off season in some cases. Data reporting at intervals of 40 days.
- Linkages with bordering countries, Pakistan (adjoining J & K, Punjab, Haryana, Gujarat, Rajasthan) and Nepal (adjoining states of Uttar Pradesh, Uttarakhand, Bihar) to ensure planting of TRAP / SAARC nurseries by end of October. Data reporting at intervals of 40 days involving CIMMYT coordinators of respective country.
- Linkage with chemical industry for supply of timely and adequate quantity of recommended fungicides to be used for emergency management of the disease.
- Exploring the areas of survival of inoculum on wheat or other grasses during off season and identifying initial infection focii. Monitoring for the stripe rust inoculum in adjoining hills of affected states and exploring the possibilities of eradication / management of such inoculum.
- Identifying the variability in pathogen at off season locations *vis a vis* that infect the wheat crop during the season based on routinely used differential set and integrating molecular tools for genetic diversity.
- Strengthening laboratory facility and human resource at IIWBR Regional Research Station, Flowerdale Shimla and IARI Regional Station, Wellington.
- Evaluation of advanced trial material at off season locations in north hilly region e.g. at Dalang Maidan / Keylong in Lahaul valley of Himachal Pradesh.
- Evaluation of advanced trial material at natural hot spots during the crop season where no artificial inoculation is carried out in Punjab, Haryana, Himachal Pradesh and J & K.
- Avoid sowing of highly susceptible genotypes such as PBW 343, HD 2733, HD 2851 and WH 711 and other un-recommended genotypes in disease prone areas.
- Establishing / strengthening facilities to dissect resistance at molecular level in the genotypes to be released for cultivation at IIWBR.
- Promoting varieties for early release specifically generated by incorporating known major / minor genes in the already released / cultivated wheat varieties - developed either through restricted backcrosses or developed near isogenic lines.
- Known gene entries falling short of further promotion/release should be confirmed for genes of interest and routed to NGSN for use as parents in breeding programmes.
- Deployed resistance will be best understood through genetic analysis. Screening of 3-4 F_2 and F_3 populations per year be accommodated in Pathology nurseries and data should be shared in the workshop report.
- Scouting of new genes for rust resistance, their cataloguing and transfer to suitable agronomic backgrounds should be supported at one or more centers.

Keeping in view the possibility of stripe rust damage to the wheat crop since 2010-11 crop season, following measures were taken:

- Replacement of susceptible varieties with resistant varieties: The meetings on strategies to enhance wheat production in north western region of the country were organized by IIWBR at Karnal on

August 14, 2010, September 24, 2011 and Oct. 5, 2012. Strategy was made to manage stripe rust in northern states of India by replacing susceptible variety, PBW 343 with resistant wheat varieties in stripe rust prone areas in J & K, Himachal Pradesh, Uttarakhand, Punjab and Haryana.

- A strict vigil was kept on the appearance of stripe rust by the crop health monitoring teams (IIWBR and SAUs scientists) from November onwards. Based on rigorous survey in the region, IIWBR, Karnal issued advisory for management of stripe rust from December onwards. Following this, state governments issued advisories. Details of Crop Health were disseminated through Wheat Crop Health Newsletter and also put on the IIWBR website.
- Task Force Meetings: Task Force Meetings were held regularly during the crop seasons (2010-11 to 2012-13) under the Chairmanship of DDG (CS), ICAR, New Delhi. This stripe rust compaign was launched successfully by IIWBR alongwith support from its co-operating centres, KVKs', ICAR and DAC. Success of this is envisaged that during 2010-11, a loss of 2-3 million tons was avoided and the country could harvest record production though many neighbouring countries faced stripe rust epidemic.
- Awareness among farmers for management of the disease was also created through web site (ICAR), newspapers, TV, radio, farmers' fairs, personal contacts, SMSs and distribution of stripe rust management cards etc.

Rust Management

It was during 2007-08 that realizing the importance of its widespread and losses incurred, necessity arose to use fungicides for its management. It was in the Ropar area of Punjab and later its spread to large number of villages. First time, initiative was taken to evaluate Propiconazole to manage it and it was initially recommended as need based. However, as farmers were not fast enough to replace the susceptible varieties, so fungicide spray was recommended. Effect of tilt (0.1 %) spraying on area under disease progress curve and yield of wheat stripe rust susceptible variety, WL 711 (Sharma *et al.,* 2009). During 2010-11, timely action of fungicide sprays resulted in avoiding losses of 2 mt of wheat.

Monitoring stripe rust of wheat

Efforts were made to monitor wheat rusts, educating the farming community and extension functionaries through awareness campaigns regarding identification and management of stripe rust through press, electronic media and literature in local languages of respective states prior to sowing of wheat crop (August – October) for choice of wheat varieties to be grown, to identify the disease symptoms. Time to time field visit for early detection of the disease, apprising them of primary focus of stripe rust infection, advising to avoid early sowing under shade / trees and management with emergency spray of recommended fungicides was also emphasized. Stripe rust of wheat appeared in several foci of infection in a field. Therefore, vigil for the occurrence of stripe rust was required after mid of December and subsequently at fortnightly intervals to manage it with fungicides at intial foci of infection. Depending upon the situation, initiatives were taken to manage stripe rust in the disease prone areas of Himachal Pradesh, Jammu & Kashmir, Punjab, Haryana, Uttarakhand and Uttar Pradesh by Agricultural Scientists, Extension specialists and Agricultural Officers working with state Department of Agriculture. If infection was visible on few plants only, the awareness was spread that the infected plants should be buried or put

in water for four hours. In case of widespread infection, fungicide could be used to restrict its spread. Infected samples of wheat stripe rust are sent for analyses at regional station of IIWBR at Shimla for identifying the pathotypes and know the shift in virulence pattern. The new pathotype if any, is used to identify the rust resistant wheat lines by evaluating the AVT material before the new pathotype reaches the epidemic proportions.

Stripe rust was also monitored through WDMN and SAARC nurseries in Jammu & Kashmir, Dalang Maidan, low hilly areas of Himachal Pradesh, Punjab, Haryana, Uttarakhand by mid of December onwards and in off season also in some locations. Data reporting at regular intervals was practised. Linkages with bordering countries, Pakistan (adjoining J & K, Punjab, Haryana, Gujarat, Rajasthan) and Nepal (adjoining states of Uttar Pradesh, Uttarakhand, Bihar) to ensure planting of SAARC nurseries by end of October is a routine. At present, these nurseries are being planted at more than 67 locations in India. Since these nurseries are quite diverse and are surrounded by two rows of susceptible checks, therefore, it became easy to know the appearance of stripe rust as well its spread. All the information generated on the monitoring of wheat rusts is complied in Wheat Crop Health news letter and Mehtaensis. Molecular tools are also being exploited to find out variation with in an isolate. Possibilities of using remote sensing for early detection of infection foci in stripe rust affected states / to get a better picture of areas affected are also being explored.

Evaluation for stripe rust resistance

To identify stripe rust resistance in India all the wheat material selected for Advance Varietal Trials are evaluated against a spectrum of pathotypes under controlled conditions at Regional Station, IIWBR, Shimla. Likewise all these entries are evaluated for Adult plant and slow rusting resistance at Shimla as well as in multi locational trial including those conducted at IIWBR, Karnal and in off-season at Wellington and Dalang Maidan. If a new pathotype is encountered, it is used to evaluate the wheat material and identify stripe rust resistant lines to be ahead of the pathogen. All the hotspot locations including Malan, (Palampur), Bajoura Dhaulakuan, Pantnagar, Almora, Gurdaspur, Ludhiana, Hissar, Khudwani, Delhi and Durgapura (Jaipur) are used for this screening. It helps in identifying lines with resistance at multilocations, slow rusting and adult plant resistance which are indirectly used in identifying diverse sources for stripe rust resistance.

Planting stripe rust resistant varieties

Since life of wheat variety is about 5 years and then it is rendered susceptible by shifting virulence of stripe rust pathogen. Under adverse environment, self life of a variety is increased as stripe rust is a very sensitive pathogen. Varietal replacement and breeding for stripe rust resistance is a continuous feature of a dynamic programme. Avoiding cultivation of highly susceptible genotypes such as PBW 343, HD 2733, HD 2851 and WH 711 and other un-recommended genotypes in disease prone areas is the foremost and important step. Stripe rust was the first disease in which host resistance was shown to be inherited in Mendelian fashion (Biffen, 1906). Some resistances are durable whereas genes have little effect, independently, but are very useful in combinations. Resistance genes with minor effects and only detectable

under certain temperature and adult plant stage are used for increasing diversity. So far 58 *Yr* genes have been designated (R. A.Mc Intosh, 2013 personal communication), yet most of them are susceptible in one part of the world or another. Alien genes were once thought to be a permanent solution to control stripe rust of wheat but even this myth did not last long. Some of the genes, viz., *Yr5, Yr10, Yr11, Yr12, Yr13, Yr14, Yr15, Yr16, Yr24, Yr26, Yrsp* are effective against Indian pathotypes of stripe rust.

Under the gamut of All India Coordinated Wheat and Barley Improvement Project, breeding for stripe rust resistance is a thrust area of North Western Plains Zone and Northern Hills Zone. Lines developed at different centres undergo station trials and best one are promoted to Advance Varietal Trial I which undergoes seedling evaluation at Shimla and multi location testing for field screening. The cream of the material of AVT I is promoted to AVT II which undergoes further seedling and field evaluation and best ones are identified for release as stripe rust resistant varieties.

A number of wheat varieties with substantial stripe rust resistance advocated to be grown at farmers fields are as follows:

North Western Plain Zone: WH1105, HD 2967, DBW 88, DPW 621-50, WHD 943(d), WH 542, PDW 314(d), HD 3086 for timely sown conditions and DBW 16, DBW 71, DBW 90, PBW 590, PBW 660, WH 1021 and HD 3043, HD 3059 for late sown conditions

Northern Hills Zone: HS 542, HS 507,VL 892, HS 375, HS 490, VL 907, HPW 349, VL 907, VL829, HPW251, VL616, HS490, VL892, HS375, VL832 and SKW196

At Flowerdale, Shimla, 13 diverse stripe rust resistant genetic stocks have been developed/registered (Table 9). Seed of these stocks was distributed to different centres and Breeders in North Western Plains Zone. In a DBT Project at IIWBR, Flowerdale, Shimla in collaboration with R.S., I.A.R.I., Tutikandi, Shimla, a number of lines with stripe rust resistance conferred by at least two genes are being developed in the background of HS 240, HS 295 and HS 424. In addition efforts are on to establish/ strengthen facilities to dissect resistance at molecular level in the genotypes to be released for cultivation at IIWBR. Promoting varieties for early release specifically generated by incorporating known major / minor genes in the already released / cultivated wheat varieties - developed either through restricted backcrosses or through generating near isogenic lines is also being initiated. Known gene entries falling short of further promotion/ release will be confirmed for genes of interest and routed to NGSN for use as parents in breeding programmes. Deployed resistance will be best understood through genetic analysis. Screening of 3-4 F_2 and F_3 populations per year will be undertaken in Pathology nurseries and data would be shared in the workshop report. Scouting of new genes for rust resistance, their cataloguing and transfer to suitable agronomic backgrounds would be supported at one or more centres.

Table 5. Stripe rust prevalence during 2011-12 crop season

Year	Place	Varieties	Intensity
J & K			
September 5, 2011	In the Indus river basin in Leh	Four by Four	Stem, leaf and stripe rusts, were observed (40-60S)
September 6, 2011	Nemo, Leh	Four by Four and club wheats	40-80S
February 4, 2012	Ghad, Panchrukhi	UP 2338	40S
January 5, 2012	Kalayna	PBW 343	30S
January 25-27, 2012	Kathua and Shamba districts	PBW 343, PBW 550, Shalimar and some unknown varieties	10S
February 9-10, 2012	Samba and Kathua	PBW 343 and PBW 502	5-80S
February 9-10, 2012	Chatha	Shalimar wheat -1 and PBW 343	10-80S
February 9-10, 2012	RS Pura	PBW 343	10S
Punjab			
January 4, 2012	Patti, Nangal	WH 711	60S
February 9, 2012	Majiri Jata Di, Gurdaspur	WH 711	80S
February 13, 2012	Rampur, Ropar	DBW 17	60S
February 13, 2012	Rurkikalan, Nawashahar	HD 2932	60S
February 14, 2012	Kahnuwan block, Gurdaspur	PBW 550, HD 2967 and DPW 621-50	60-80S
Haryana			
February 6, 2012	Yamunanagar: Bhamnoli, Rattuwala, Safeelpur, Nijampur, Rajpur, Kaloudi, Rathali, Thaska, Mirzapur, Baroulimajra, Sadhoura and Bilaspur	PBW 343, WH 711, HD 2851, DBW 17, PBW 550, Raj 3765, Super 172 and HD 2894	PBW 343, WH 711 and Super 172. (10-20S)
February 14, 2012	Dabkoli Khurd, Indri Block of Karnal	DBW 17	20S
HP			
February 14, 2012	Sunhera, Una	PBW 550	10S
February 3, 2012	Indora, Nagrota Surian blocks Karol, Pragpur block	HS 240	40-80S
February 4, 2012	Chandrika) at Ichhi (Kangra block)	HPW 184	60S

Uttarakhand			
February 17, 2012	Busbheeda (Chaukhutia block, District Almora),	UP 2338	80-90S
	Busbheeda, Chaukhutia and Chinoni		10-30S

Table 6. Stripe rust prevalence during 2012-13 crop season

Year	**Place**	**Varieties**	**Intensity**
Punjab			
January 9, 2013	Mehindpur (near Chidouri, Saheed Bhagat Singh Nagar)	-	10S
Mid January, 2013	Surewal in Ropar district	-	20S
Mid January and 1st week of February	SBS Nagar and Ropar	DBW 17, PBW 550 and PBW 343	20S
1st week of February, 2013	Hoshiarpur	-	40S
Mid February, 2013	Shergarh, Fassemand, Mohan Majra, Lakhewal, Bela, Rasidpur, Fatehgarh Veera and Balowal (Ropar)	HD 2733, HD 2894, WH 711, PBW 343, Barbet and PBW 550	20-40S
Mid March, 2013	Near Satluj river bundh in a radius of 1 Km in villages Shergarh and Fasse Mand in Ropar district	HD 2733, HD 2894, WH 711, PBW 550, Barbet	40-60S
Mid March, 2013	LudhianaSBS Nagar (Mahindpur, Chhidhouri, Ballowal Saunkhri, Saroya, Mujowal Majara, Majari, Langroya, Taprian). In Ropar (Surewal, Mothapur, Fatehgarh Veeran, Mohan Majra, Sultanpur, Shergarh, Sarangpur, Lakhewal, Abhiyana, Dhahe, Phasemund	DBW 17, PBW 550, HD 2967, DPW 621-50	5-40S
Mid March, 2013	Hoshiarpur	HD2967, DBW17, PBW 550, Barbet, HD 2733 and un-recommended varieties	5-40S
Last week of March, 2013	Gurdaspur, Patiala, Amritsar, Bhatinda, Ludhiana, Sangrur, Faridkot, Jallandhar, Fathegarh Sahib and Ferozpur	DBW 17, PBW 550, HD 2967, DBW 17, PBW 550, HD 2967, DPW 621-50, DBW 17 and PBW 550	5-20S
Last week of March, 2013	57 villages of Hoshiarpur.	HD 2967 and DPW 621-50. on varieties Super 172, WH 711, DBW 17, PBW 550, HD 2894, DPW 621-50 and HD 2967.	20-40S

Haryana			
January 30-31, 2013	Madhubans (Radaur, Yamunanagar)	HD 2967, DBW 17	10S
February 27, 2013	Sadhoura block (450 villages), Jaroda (Jagadhari block), Yamunanagar	Super 172, WH 711, HD 2851, Raj 3765, HD 2967	10-60S
Mid March, 2013	258 villages in Yamunanagar district	Most of varieties grown	10-40S
HP			
First week of June, 2013	Kullu Hills near Bajoura	Self grown wheat	20S
J & K			
February 11, 2013	RS Pura	RAJ 3077	20S
February 11, 2013	Davigarh, Bulla Chak (RSPura tehsil, Jammu), Ramgarh (Anandpur) andMatalkaliu (Samba district)	DBW 17 and RAJ 3077	10 - 20S
March 1, 2013	Raphta, Hore, Sohal, Rabita, Derababa, Ambala, Derababa KVK farm, Kotli, Jitoo (Jammu)	PBW 175	20S
Uttarakhand			
February 26, 2013	Tarai/plains of Uttarakhand enrouting Rudurpur (villages Dhaulpur, Jafarpur, Bhagwanpur and Danpur), Ineshpur (vill. Kalinagar, Jagdeshpur and Srirampur), Gadarpur(villages Haripura maseed, Surajpur, Sultanpur and Jhagarpuri), Bajpur (villages Barhaini, Bhattipuri namunaand and Namoona) and Kashipur (villages Shankarpuri, Piplia, Khadakpurand Kunda gaon and Kelakheda).	PBW 343, PBW 154, DBW 17, PBW 502 and UP 2338	TS
February 27, 2013	Pantnagar and Khatima enroute Kichha (villages Sirsa chowki, Uttam Nagar, Bari farm and Kathangari), Sitarganj (villages Kamanipur, Turkattisor, and Nakha farm), Nanakmatta and Khatima (villages Peniya, Gurkunda, Patpura and Bhangali)	PBW 343, PBW 154, PBW 226 and UP 2338	TS-50S

Table 7. Stripe rust prevalence during 2013-14 crop season

Year	Place	Varieties	Intensity
Haryana			
January 1, 2014	Ratangarh, Yamunanagar	WH 711	10S
Upto February 28, 2014	40 farmers fields in 25 villages in Yamunanagar, 15-20 farmers fields in Karnal, five villages (Darba, Paniwala Mota, Bhagsar, Audhan and Bara Gurha) in the periphery of 5-10 km in Sirsa (small foci of yellow rust in the range of 20-30S) and one village in Ambala.	WH 711, HD 2932, HD 2851, HD 2967, DPW 621-50, Shri Ram 271, DBW 16, DBW 17 and Barbat HD 2851, WH 147 and PBW 343	10-40S
Punjab			
January 6, 2014	Dabkheraupralla, Roop Nagar and Bare Bajwara, Hoshiarpur	HD 2967 and PBW 550	5-10S
January 21, 2014	Tahlar, Zone Arnia, RS Pura	DPW 621-50	40S
February-March, 2014	Mohali, Gurdaspur, Ludhiana, Amritsar, Fatehgarh Sahib, Patiala and Bhatinda	PBW 550, HD 2967	40S
J & K			
Last week of February, 2014	Udhaywalla, Marh, Chinor, Akhnoor, Jammu, RS Pura, Bishna (Jammu district) and Vijaypur (Samba District)	PBW 343, Sonalika, WH 711, PBW 550, PBW-175, RAJ 3077 and RAJ 3765 DPW 621-50 and HD 2967	20-80S
UP			
Last week of March and 1st week of April	Western UP	On most of the varieties grown	10-60S
HP			
January 17, 2014	Dhaulakuan, Sirmour	TPN (Kharchia mutant) and SAARC (Agra Local) nurseries	10S
1st week of February, 2014	Mandi, Una, Hamirpur and Bilaspur	Local varieties	TS
2nd fortnight of March, 2014	Chandpur, Majari, Bassi Dabt, Auhar, Bhaani, Reshikesh, Luharwin and Tikkri (Bilaspur)	Local varieties	TS
April, 2014	Hamirpur, Kullu, Mandi, Sirmour, Shimla, Solan, Una and Kangra	HPW 251, VL 829, VL 616, HS 277, HPW 184, HPW 211, HS 240, VL 738, VL 804, DBW 17, Raj 3765, PBW 343, PBW 502, PBW 550, WH 711, Super 369, Sonak, Kanaku, HPW 42, HS 295, HS 420, VL 892, Raj 3777, Sonalika	40-80S

2nd week of June, 2014	Kullu areas in village Bhalayani	Local wheats	60-80S
Uttarakhand			
Last week of February, 2014	Khatima block of Udham Singh Nagar (Uttarakhand)	PBW 343, PBW 502, HD 2967, PBW 550 and DPW 621-50	20S
May 19, 2014	Bhowali (Uttarakhand)	Indigenous germplasm	60-80S

Table 8. Stripe rust prevalence during 2014-15 crop season

Year	Place	Varieties	Intensity
Haryana			
January 16, 2015	Yamunanagar	-	10S
January 16, 2015	Munda khera, Chhachhurali and Pahadipur, Sadhaura	Berbet and Super 172	40-60S
January 28, 2015	Mahua Kheri, Babbain (Kurukshetra)	HD 2851	10S
January 31, 2015	Chhapra, Ambala	-	10S
February 9, 2015	Jaloda, Yamunanagar	HD 2967	10S
2nd and 3rd week of February, 2015	Bharwabgarh, Budhia (5S), Fatehgarh (20 - 40S), Shargarh, Karnal (TS) and Ding, Sirsa (TS)	HD 2851	TS-40S
Punjab			
December 19, 2014	Daroli Upper near Anandpur Sahib	Berbet	10S
2nd week of January, 2014	Chhidauri, Kharod(SBS Nagar) and Mohan Mazra (Ropar)	DBW 17 and HD 2967	10S
January 29, 2015	Dakal, Ropar	HD 2967	20S
February 18, 2015	Langroya, Jagmeenpur, Rattewal (10S) Pasredi Jatta Chamkaur Sahib, Morinda and Ropar (80S)	HD 2967	10-80S
On 19.2.2015,	Langroya to Saroa (10S), Diyall (60S), TRAP plot nurseries at KVK Langroya and KVK Ropar (TS)	HD 2967	10-60S
J & K			
January 8, 2015,	Village- Saharan)	SAARC and TPN nursery (Agra Local)	TS
January 25, 2015,	Lalyal Camp, Jammu	PBW-175	5S
January 26, 2015,	Chak Gogal, Nagari, Kathua and Arnia	HD-2967 and RSP 561	20MS-20S
February 10, 2015	Jammu and Samba district in Jammu region.	Local varieties	10-60S

HP			
Last week of January, 2015	Nagrota Suria Dam area (Nagrota Surian block) and Lunj Kahlian (Kangra block), Bhanth (Fatehpur block) and Bhanth-Sthana (Fatehpur block).	PBW 550, HD 2967 and RAJ 3765	10S 60S at Bhanth-Sthana (Fatehpur block)
2nd week of February, 2015	Barotiwala (Paonta)	HD 2967	TS
February 10, 2015	Dhaulakuan	In Trap nurseries: WL 711, HD 2329 , Agra local, HW 2021, Lal Bhadur, Kharchia mutant, HP 1633, WH 147, Anna Purna, HD 2189 and Pak 81	5-30S
February 16, 2015	Bharapur and Kolar	Local wheats, HD 2967	40-60S
1st week of February, 2015	Bilaspur, Hamirpur, Kangra, Mandi, Sirmour and Una	Local varieties	TS
2nd week of February	Nanawan and Bhatoli (Bilaspur), Mehar, Surahi, Tandu (Mandi), Adarsh Nagar, Amb, Athwan, Krishna Nagar, Busal, Dehar, Badoh, Jalgran (Una) and Dhaun, Bhangani, Nagal, Phoolpur, Shivpur, Subhkhera, Surajpur (Sirmour)	Local varieties	TS
Uttarakhand			
On 16 Feb 2015,	Chunpuri (Gadarpur) in patches in (1Ha).	PBW 343	70S

Table 9. Stripe rust genetic stocks developed at IIWBR, Flowerdale, Shimla

Sl	Name	INGR Number	Pedigree	Characteristic features	Genes
1	FLW3	03015	UP2338/China-84	Resistant to stripe and stem rusts	*Lr26+Sr31+Yr9+YrChina-84*
2	FLW10	-	WH542/Moro	Resistant to stripe and stem rusts	*Lr26+Sr31+Yr9+Yr10*
3	FLW11	05003	WH542/Hobbit	Resistant to stripe and stem rusts	*Lr26+Sr31+Yr9+YrHobbit*
4	FLW12	05004	UP2338/Mega	Resistant to stripe and stem rusts	*Lr26+Sr31+Yr9+YrMega*
5	FLW13	05005	WH542/Yr15	Resistant to stripe and stem rusts	*Lr34+Sr2+Yr15+Yr18*

6	FLW16	-	UP2338/*Triticum spelta album*	Resistant to stripe and stem rusts	*Lr26+Sr31+Yr9,Yr5*
7	FLW17	-	WH542/Spalding Prolific	Resistant to stripe and stem rusts	*Lr26+Sr31+Yr9,YrSP*
8	FLW21	-	UP2338/Centurk// UP2338/Yr15	Resistant to all rusts	*Lr26+Lr24+Sr24+ Sr31+Yr9+Yr15*
9	FLW22	-	WH542/Lr28// WH542/China84-40022	Resistant to all rusts	*Lr26+Lr28+Sr31+Yr9+ YrChina-84*
10	FLW28	08001	PBW343/PH137	Resistant to leaf & stripe rusts	*Lr19+Lr24+Lr26+Sr24+ Sr25+Sr31+Yr9+*
11	FLW29	08002	PBW343/CD// PBW343/Lr28	Resistant to all the rusts	*Lr26, Lr28, Sr31, Yr9, YrCD*
12	FLW30	08003	PBW343/Yr15// PBW343/Lr28	Resistant to all the rusts	*Lr26, Lr28, Sr31, Yr9, Yr15*
13	RNB1001	05007	HD2687/MACS2846	Resistant to leaf and stripe	*Lr* unknown, *Yr* unknown

Strategy meetings and awareness compaign:

Strategy meetings were also held regularly during the crop seasons (2012-13 to 2014-15) under the Chairmanship of Secretary DAC / Agriculture Commissioner, G. O. I. on October, 2013 in Panchkula (Haryana), Dehradoon (Uttarakhand) and Jammu (J & K), in Una (HP) on January 8, 2014, in Lucknow (UP) on Oct. 16, 2014, in Panchkula (Haryana) on January 20, 2015, in Bhopal (MP) on January 28, 2015. Advisory for stripe rust management was issued by IIWBR Karnal 4-5 times during the season every year. Awareness among farmers was created about detection of stripe rust, its management through web site (ICAR), newspapers, TV, radio, farmers' fairs, training programmes, personal contacts, on the spot interaction, SMSs and distribution of stripe rust management cards etc. It was made clear to the farmers that yellowing of plants is not stripe rust. By touching the yellow leaves if yellow powder sticks to fingers only then it could be the disease.

Training Programmes Organized (2007-2015)

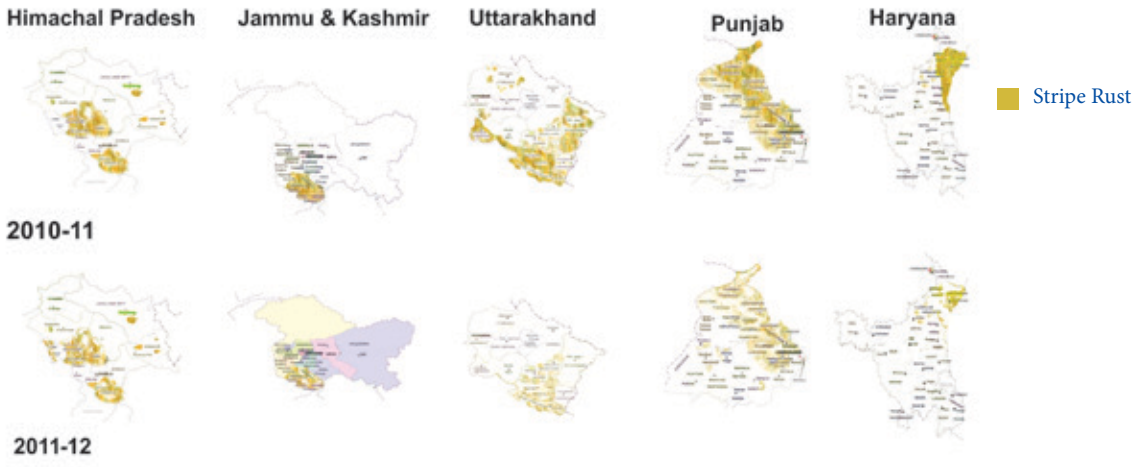
- A refresher course on techniques in crop protection and data generation in wheat and barley was organized at IIWBR, Karnal from 28th February to 2nd March 2007 for co-operaters of AICW&BIP.
- A 21-day long winter school on "IPM in Wheat Based System' was organized at IIWBR, Karnal during March, 2008.
- A hands-on training on "Techniques and Procedures in Wheat Crop Protection for Field Evaluation of Host resistance" was organized at IIWBR, Karnal on March 18-19, 2010.
- A training programme on "Wheat Rust Surveillance and Monitoring" was organized in collaboration with DRRW-BGRI (Cornell University) from February 26, 2010 to March 13, 2010. The participants were from Afghanistan, Bangladesh, Nepal and India.

- Training of state level officers of Agriculture Department & SKUAS&T at Jammu was organized on January 10, 2012.
- Orientation course on "Wheat diseases with special focus on stripe rust (stripe rust) management" was organized on January 11, 2012 at IIWBR, Karnal for the functionaries and officers of KVK's and SAU's etc.
- Training course on stripe rust management for ADO's and others from Haryana State Deptt. of Agri. (Panchkula, Ambala & Yamunanagar Districts) was organized by IIWBR on 17.01.12 at DDA Office, Yamunanagar.
- Training course on stripe rust management for ADO's and others from State Ag. Deptt. Karnal Distt., was organized on January 17, 2012 at IIWBR, Karnal.
- A training programme on stripe rust was held at Yamunanagar on February 6, 2012.
- Training on stripe rust management was conducted for ADO's of Haryana State Department of Agriculture at KVK, Rohtak on February 24, 2012.
- Training programme on 'Wheat Rust Surveillance and monitoring" was organized by DRRW-ICAR on March 4-5, 2012, at IIWBR, Karnal for SAARC countries.
- Training programme for officers and scientists of CIPMC's of Govt. of India was organized on March 19, 2012 at IIWBR, Karnal.
- Training programme on "Prevalence of stripe, brown and black rust" was organized on September 21, 2012 at KVK Leh under the SKUAST, Srinagar.
- Training programme was organized on stripe rust management at Mashobra (Shimla) by Department of Agriculture, HP, SAMETI and IIWBR, Karnal.
- Highlighted the stripe rust management in seminar organized by Haryana Kisan Ayog in NDRI auditorium on December 22, 2012.
- Organized Farmers' Fair in village Veeram (Amritsar) on December 27, 2012.
- Highlighted the stripe rust management in Agriculture Department Officers meeting held at IIWBR, Karnal on February 4, 2013. Stripe rust surveillance course was organized in collaboration with BGRI, Cornell University during January 29-31, 2014 at IIWBR, Karnal for co-operators of AICW&BIP.
- International collaboration with BGRI through Cornell University / Sathguru Management Consultants Pvt Ltd has strengthened the rusts surveillance and information sharing on wheat rust occurrence in South Asian countries through online surveillance tool box.
- Remote sensing software was also deployed to detect the areas affected by stripe rust and training to scientists was imparted by ISRO, Ahmedabad under joint collaborative project of IIWBR, Karnal and ISRO, Ahmedabad.

The fields have been depicted wherein impact of propiconazole in managing wheat diseases is evident. Awareness compaign through cards is shown in Fig. 2. There has been reduction in area which remained either disease free or showed disease in less intensity after 2011-12 (Fig. 3). Information

Fig. 2. Stripe Rust Management Cards

Fig. 3. Following figures relevant to depict the reduction in stripe rust during 2011-12 by adoption of management practices has been shown below:



regarding the first report of the disease was generally received by the scientists involved in surveys for monitoring wheat diseases but ever since the farmers got aware about its detection, the first report of disease occurrence is now being received from the farmers. In last 3-4 years, though the disease has been detected very early (December / January) in one or the other state but timely spraying of fungicide restricted the disease in the intial infection foci (areas) limiting its spread to large areas. Timely detection and availability of fungicides played crucial role in avoiding losses to wheat crop in these years under situations of early detection and environment (climate) being highly conducive to its spread. There would have been losses in north western plain and northern hilly areas which were averted and India produced record production during 2013-14 inspite of favourable weather for the disease development and spread.

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