Bangladesh J. Bot. **51**(4): 647-653, 2022 (December) DOI: https://doi.org/10.3329/bjb.v51i4.63481

IMPACT OF STRIPE RUST ON YIELD LOSS OF WHEAT AND ITS STATUS IN HARYANA, INDIA

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Key words: Wheat, Stripe rust, Yield loss, *Puccinia striiformis* f.sp. *tritici*

Abstract

Stripe rust caused by *Puccinia striiformis* f. sp. *tritici* (Pst) is a major constraint in all wheat-growing countries. Surveys conducted during 2015-19 in Haryana, maximum stripe rust severity recorded in Yamuna Nagar (28.57%) followed by Ambala (23.33%) and least observed in Fatehabad (5%).Two commonly prevalent pathotypes 46S119 and 110S119 were in all 4 crop seasons followed by 238S119 occurrence in two seasons. Infection range was 0-80S in varieties HD2967, Shri Ram152, Shri Ram171, Shri Ram3132, Barbett, WH147 and HD2851. Maximum terminal disease severity contracted by WH 147 (100%), HD2967 (100%) and PBW 343(96.66 %) in seedling stage disease appearance followed by tillering stage and least disease severity was observed on milk development. Stripe rust symptoms produced 14 days after artificial inoculation with urediniospores (10^6/ml) of *Puccinia striiformis* f. sp. *tritici*. Maximum avoidable yield loss was obtained in WH 147 (73.14%) followed by HD2967 (68.35%), PBW343 (60.08%) and least recorded in WH1105 (20.26%) on seedling stage. Minimum yield loss in varieties was recorded at milk development stage. There was significant correlation (0.90) between disease severity and avoidable yield loss with the coefficient of determinant, R^2= 0.80.

Introduction

Wheat is consumed by more than 40 % of the human population. Wheat based products are rich source of carbohydrates, potassium, iron, thiamine, niacin and dietary fibre. India is the second largest producer of wheat after China. During 2020-21, wheat output of India has a recorded level of 109.52 mt with an average national productivity estimated at 3464 kg/ha. The state of Haryana, second largest wheat contributor to central pool of India occupies 25.21 lakh hectares area with production of 121.54 lakh tonnes during 2020-21 (ICAR IIWBR 2021).

Globally, three rusts occur differentially depending on the weather conditions and genotype array of the region (Chen 2005, Chen *et al*. 2014). Seedling and tillering stage infection resulted in heavy yield losses of 50-100% (Nadeem *et al*. 2007). Severe yellow rust can cause more than 90% yield losses in a field (Chen *et al*. 2014). Stripe rust can cause loss in yield varies from 4.2-68.8% in different varieties of wheat in the north-western parts of India (Prashar *et al.* 2007). The disease caused loss of Rs 236 crore in Punjab (Jindal *et al.* 2012). The worldwide estimated losses caused by wheat rusts were USD 170 million for stripe rust in Pakistan, AUD 100-200 million for stem rust in Australia (McIntosh *et al.* 2009). One-billion USD annual losses is estimated due to the severity and around 90% of the world's wheat crop is vulnerable to stripe rust (Schwessinger 2017). Recently, it has appeared in severe form in north-western regions of India including Haryana and led to heavy losses in yield. Therefore, the present investigations were made to estimate avoidable yield losses on appearance of stripe rust at different phenological growth stage of wheat.

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Materials and Methods

Fresh urediniospores of eight pathotypes of *Puccinia striiformis* f. sp. *tritici*(Pst)*viz*, 46S119, 110S119, 110S84, 238S119, 78S84, 47S103, 6S0 and 7S0 obtained from the Indian Council of Agricultural Research, Indian Institute of Wheat Barley Research (ICAR IIWBR) Regional Station, Flowerdale Shimla (Himachal Pradesh) in November 2015, 2016, 2017 and 2018. The pathotypes were regularly multiplied for further usage on vulnerable wheat variety Kharchia 65, Lal Bahadur and Agra local raised in earthen pots.

The two leaf seedlings of cultivar Kharchia 65, LalBahadur and Agra local inoculated with urediniospores of pathotypes 46S119, 110S119, 110S84, 238S119, 78S84, 47S103, 6S0 and 7S0 for maintenance and multiplication. These seedlings kept at 11±2ºC for 48 hrs and humidity was offered for 48 hrs in moist chamber. Then these were incubated at 12 ± 2ºC in plant growth room. The urediniospores collected after 14 days of inoculations on parchment paper by gently tapping the infected leaves. The butter papers containing urediniospores kept in the air-tight glass vials and then stored in the refrigerator (-20^{0}C).

Roving and continuous surveys conducted in stripe rust prone area of Haryana to understand the present disease status and the prevalence of different pathotypes. The surveys conducted after every 10-15 km distance at 5 spots in each location diagonally during the crop seasons 2015-19 in different districts of Haryana and terminal stripe rust severity recorded through 20-25 March in each crop season using Modified Cobb scale (Peterson *et al*. 1948). Sub-mountainous area of Yamuna Nagar and Ambala were intensively monitored to find initial infection of stripe rust during December 2015 to March 2019. Stripe rust infected leaves samples collected from the farmer's fields of Karnal, Kurukshetra, Kaithal, Panipat, Sonipat, Rohtak, Jhajjar, Jind, Hisar, Sirsa and Fatehabad districts from different varieties. Dried leaves wrapped in parchment paper labelled properly, enclosed into envelope and parcelled to ICAR IIWBR Regional Station, Flowerdale Shimla for virulence analysis of different isolates.

Wheat variety WH147, PBW343, HD2967 (highly susceptible) and WH1105 (moderately susceptible) were sown in 15-25 November 2015-2018 in research area of Department of Plant Pathology, Ch.Charan Singh Haryana Agricultural University (CCSHAU), Hisar in randomized block design to assess avoidable yield loss at different growth stage appearance due to stripe rust. For each variety comprises (8 treatments) of 7 different growth stages (Zadok's scale 1974) include 1-seedling), 2-tillering), 3-stem elongation), 4-booting, 5–awn emergence, 6-flowering (complete anthesis), 7-milky stage, 8 check – one leaf stage inoculated with Pst urediniospores (10^6/ml) and spray with water. For each treatment of crop growth stage, plot size of 2.5 x 2 m^2 used in triplicate. *Puccinia striiformis* f.sp.*tritici* (mixture of 46S119, 110S119, 110S84, 238S119, 78S84, 47S103, 6S0 and 7S0 pathotypes) urediniospores (10^6/ml) spray inoculation as well as infectors/stripe rust spreader (Kharchia 65, Agra local and Lal Bahadur) raised on earthen pots kept in furrows for each treatment of above mentioned wheat growth stages of 14 days prior to appearance of stripe rust. For each growth stage disease appearance, check/control was also maintained by protecting through prophylactic spray of mancozeb @ 0.4% at 7 days interval. Check (water) was inoculated with Pst pathotypes mixture urediniospores (10^6/ml) at seedling stage and terminal stripe rust severity was recorded through modified Cobb scale (Peterson *et al.*, 1948) for each crop growth stage treatment. Yield per plot of each treatment was calculated on basis of Kg/ha. Correlation and regression between avoidable yield loss and disease severity was computed using OPSTAT Software (http://hau.ac.in).

Result and Discussion

Survey carried out during 2015-19, initial foci of stripe rust observed in January at farmers field of Naraingarh (Ambala), Bilaspur and Radaur (Yamuna Nagar) on genotype Shri Ram (SR) 3122, SR 152, SR171, Barbett and variety HD 2967 since these are located at Himalaya foothills or proximity of primary source of inoculum. It was noticed in traces in small area of highly susceptible genotype and then spread to other susceptible varieties in nearby fields. The varieties like WH 1105 and HD 3086 were resistant at farmer's field Survey conducted during 20-25 March at different districts of Haryana to record terminal stripe rust severity on different cultivated varieties/ genotypes is depicted in Table1. Maximum stripe rust severity was recorded in Yamuna Nagar (28.57%) followed by Ambala (23.33%) and least observed in Fatehabad (5%). In Yamunanagar and Ambala, infection range was 0-80S in different varieties. It may be due to Yamuna Nagar and Ambala near to foot hills of Himayalan range carrying off season wheat plants bearing urediniospores as well as prevailing requisite weather conditions conducive for sporulation of Pst. In Jind, Rohtak, Jhajjar, Sirsa, Fatehabad and Hisar infection range was 0-40S. The most predominant cultivated varieties at farmers' fields were HD2967, HD3086, WH1105, HD2851, WH1124, WH1142, WH711 and PBW550 PBW660, PBW725 (Table 1). The varieties HD3086, WH1105, WH1124 and WH1142 were resistant to stripe rust in Haryana.

Table 1. Status of stripe rust of wheat in different districts of Haryana during 2015-19.

Location (District)	Name of variety/genotype	Per cent mean terminal disease severity (Infection Range)
Yamuna Nagar	HD2967,HD2851,HD2894,HD3086,WH1105,PBW550,PBW725,ShriRam152,ShriRam171,ShriRam3132 and Barbett	28.57 (0 -80S)
Ambala	HD2967, HD2851, HD3086,Shri Ram 152, Shri Ram171, Shri Ram3132, PBW 550, PBW725, DBW17, Barbett, C306, WH1105, WH1021, WH1124 and WH1142	23.33 (0 -80S)
Karnal	HD2967,HD2851,HD3086, Shri Ram 152,Shri Ram171, Shri Ram3132, PBW550, PBW725, DBW17 and WH1105	15.00 (0-80S)
Kurukshetra	HD2967, HD2851,Shri Ram 152, Shri Ram171, PBW 550, PBW725, DBW17, WH1105 and HD3086	13.33 (0-80S)
Kaithal	HD2967, HD2851,PBW343, PBW 550, PBW725, DBW17, WH1124, WH1105 and HD3086	12.5 (0-60S)
Panipat	HD2967, HD2851,Shri Ram 152,PBW343, PBW 550, DBW17, WH1105 andHD3086	16.66(0-80S)
Sonipat	HD2967, HD2851, HD3086, DBW17, WH1105, WH542, WH147, WH1124, WH1142,PBW343, PBW 550 and WH711	7.5(0-60S)
Rohtak	HD2967, HD2851,HD3086, PBW 550, DBW17, WH1105,WH542, WH147, WH1124, WH1142,PBW343, PBW 550, WH1105 and WH711	6.83(0-40S)
Jhajjar	HD2967, HD2851, HD3086, PBW343,PBW 550, DBW17, WH542, WH147, WH1124, WH1142,WH1105 and WH711	5.5(0-40S)
Jind	HD2967, HD2851,PBW 550, PBW343, DBW17, WH1105, HD3086, WH711 WH542, WH147, WH1124, WH1142,PBW343, PBW 550, WH1105 and WH711	8.25 (0-40S)
Sirsa	HD2967, HD2851, HD2894, HD3086, WH542, WH147, WH1124, WH1142,PBW343, PBW 550, WH1105 and WH711	11.6 (0-60S)
Fatehabad	HD2967, HD2851, HD3086, PBW725, WH711,WH1105,WH1124 and WH1142	5.00 (0-40S)
Hisar	HD2967, HD3086, HD2851 WH1124, WH1142, PBW 550, WH1105 and WH711	6.66 (0-40S)

Stripe rust infected leaves were collected from the farmers' fields from different districts of Haryana and analysed at ICAR IIWBR Regional station for prevalent pathotypes. On the basis of analysis of stripe rust infected leaves samples revealed the occurrence of two commonly prevalent pathotypesi.e.46S119 and 110S119 in all 4 crop seasons followed by 238S119 in two seasons, whereas110S84, 46S103, 47S103,7S0 and 6S0 in one crop season (Table 2).

Table 2.Prevalence of *Puccinia striiformis* f.sp*tritici* pathotypes in Haryana during 2016-2019.

Crop season	Pathotypes							
	46 S 119	110S 119	238S119	110S 84	46S103	47S103	7S0	6 S0
2015-16	+	+	+	+	+	-	-	-
2016-17	+	+	-	-	-	-	+	-
2017-18	+	+	-	-	-	-	-	+
2018-19	+	+	+	-	-	-	-	-

+ and – indicate presence and absence,respectively.

Newly released varieties occupying large geographical area have become susceptible to newly emerged pathotype. The pathoype 46S119 virulent on *Yr9* identified in the year1996, and new pathotype 78S84 of Pst virulent on PBW343 (*Yr27*) were detected from Haryana in year 2001 (Prasher *et al.* 2007). It was also noted by Pannu *et al.* (2010) that the disease intensity and frequency of occurrence of pathotype78S84 in infected samples remained low. Changes in pathotypes frequency may be due to monoculture of resistant variety. The new pathotypes virulent on the *Yr8* and *Yr9* acclimatize to high temperature have also been identified in North America in the year 2000 (Milus *et al.* 2009). New pathotypes of stripe rust recorded from the Switzerland proved pathogenic on resistant varieties (Anon, 2010). Five new pathotypes of *Pst viz.* 46S117, 110S119, 238S119, 110S247 and 110S84 have been reported from India. Pathotype 110S119 was usually available in infected leaves, which corroborate present findings. Most of the new pathotypes of stripe rust are more aggressive. Due to increased area of HD2967, pathotype 46S119 of Pst remained predominant (Gangwar *et al.* 2021).

Artificial inoculation of pathotypes 46S119, 110S119, 110S84, 238S119, 78S84, 47S103, 6S0 and 7S0 on susceptible varieties showed maximum terminal disease severity in WH 147 HD2967 (100%) and PBW 343 (96.66%) in seedling stage which was followed by tillering stage and least disease severity observed on milk development *i.e.* 13.33, 10 and 8.33%, respectively. Subsequently disease severity decreased in booting, awn emergence and flowering stage in all varieties (Table 3).

Maximum avoidable yield loss was obtained in WH 147 (73.14%) followed by HD2967 (68.35%), PBW343 (60.08 %) and least was recorded in WH1105 (20.26%) on seedling stage. With the increase in plant age there was decrease in disease severity (Table 3). Maximum yield loss was expressed in WH147 from 5.55 to 73.14 % and minimum was recorded in WH1105 from 0.36 to 20.26% in milk development to seedling stage disease appearance. Most commonly cultivated and maximum area occupying variety in Haryana was HD2967, yield loss was 3.03 to 68.35% (Table 4). Chen (2005) observed 100 % yield loss in highly susceptible wheat cultivars under congenial weather conditions. Depending upon the crop growth stage at which 100% infection appeared that resulted in the yield loss at seedling and tillering stage was 95%, in stalk formation 70%, in booting 50%, in flowering 35%, in milky stage of the grain 20%, and in dough stage of the grain, 10 %was reported by Solis-moya 2007, which get positive support from present study. There was also significant correlation (0.90) between disease severity and avoidable yield loss with the coefficient of determinant, R^2 = 0.80. It was statistically highly significant and regression equation was also developed. Yield loss = 4.036 + 0.683 × DS (disease severity), R^2 = 0.80.

Table 3. Wheat stripe rust severity on artificial inoculation of *Puccinia striiformis* f.sp *tritici* at different phenological growth stages during 2015-19.

Wheat growth stage	Plant age (days)*	Per cent mean terminal disease severity			
		HD 2967	WH 147	PBW343	WH 1105
Seedling	18	100	100	96.66	30.00
Tillering	32	100	100	86.66	26.66
Stem elongation	47	93.33	96.66	76.66	20.00
Booting	72	83.33	86.66	66.66	15.00
Awn	92	63.33	66.66	43.33	11.66
Flowering	106	43.33	46.66	25.00	6.66
Milk development	125	10.00	13.33	8.33	1.33
CD (p=0.05)		5.88	6.79	5.71	4.27

*Plant age at the time of stripe rust appearance and 14 days prior to appearance of stripe rust, plants were inoculated artificially with Pst urediniospores (pathotypes mixture i.e. 46S119, 110S119, 110S84, 238S119, 78S84, 47S103, 6S0 and 7S0)

Table4. Assessment of avoidable yield loss owing to wheat stripe rust on artificial inoculation of *Puccinia striiformis* f.sp. *tritici* at different phenological growth stages during 2015-19.

Wheat growth stage	Plant age* (days)	HD 2967(Kg/ha)		WH147(Kg/ha)		PBW343(Kg/ha)		WH1105(Kg/ha)	
Seedling	18	5120**	1620*** (68.35)****	4560	1210(73.14)	4810	1920(60.08)	5330	4250(20.26)
Tillering	32	5115	1840(64.02)	4580	1540(66.37)	4840	2400(50.41)	5350	4410(17.57)
Stem elongation	47	5140	2320(54.86)	4590	1810(60.56)	4865	2980(38.74)	5380	4560(15.24)
Booting	72	5160	2840(44.96)	4610	2220(51.84)	4880	3450(29.30)	5420	4790(11.62)
Awn (50% earhead emergence)	92	5180	3860(25.48)	4630	3280(29.15)	4920	4010(18.49)	5460	5080(6.95)
Flowering (complete anthesis)	106	5210	4320(17.08)	4650	3710(20.21)	4950	4295(13.23)	5490	5340(2.73)
Milk development	125	5270	5110 (3.03)	4680	4420(5.55)	4990	4850(2.80)	5500	5480(0.36)
Check(water)			1620(100)		1210(100)		1920(100)		4250(100)
CD (p = 0.05)	-		415		402		398		219

*Plant age at the time of stripe rust appearance **=Protected, *****=Unprotected and **** = per cent yield loss

Conclusively, two pathotypes 46S119 and 110S119 were present. Disease severity decreased in booting, awn emergence and flowering stage with enhancement in plant age that may be due to adult plant resistance genes become active or functional or operative. Maximum yield loss was expressed by WH 147 and HD2967.

Table 5.Correlation between disease severity and avoidable yield loss on pooled basis.

	Yield loss (%)
Disease severity (%)	0.90**

Analysis of variance

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Regression	1	1,398.597	1,398.597	20.764	0.00607
Error	5	336.776	67.355		
Total	6	1,735.374			

Regression coefficients, standard errors and t-values

Variables	Coefficients	Standard Error	t-value	Significance
Disease severity (%)	0.683	0.150	4.557	0.004
Constant	4.036			

Yield loss = 4.036 + 0.683 × DS (disease severity), $R^2 = 0.80$.

Acknowledgement

Author is thankful to Head of Department of Genetics, Plant Breeding and Plant Pathology for providing necessary facilities to conduct the experiments.

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(Manuscript received on 22 December, 2021; revised on 29 October, 2022)