The Pharma Innovation Journal 2021; 10(8): 917-921

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(8): 917-921

www.thepharmajournal.com
Received: 23-06-2021
Accepted: 30-07-2021

Harshraj Kanwar
Division of Plant Pathology, RARI, Durgapura, SKNAU, Jobner, Jaipur, Rajasthan, India

Pradeep Singh Shekhawat
Division of Plant Pathology, RARI, Durgapura, SKNAU, Jobner, Jaipur, Rajasthan, India

Virendra Kumar
Division of Plant Pathology, RARI, Durgapura, SKNAU, Jobner, Jaipur, Rajasthan, India

Corresponding Author:
Harshraj Kanwar
Division of Plant Pathology, RARI, Durgapura, SKNAU, Jobner, Jaipur, Rajasthan, India

Prospecting the effect of sowing dates and epidemiological factors influencing the development of stripe rust of barley

Harshraj Kanwar, Pradeep Singh Shekhawat and Virendra Kumar

Abstract
Stripe rust caused by *Puccinia striiformis* f. sp. *hordei* is most important foliar disease of barley causing severe loss in favourable conditions. Stripe rust occurs in epidemic form in cool and moist regions. The epidemiological factors influence the incidence and severity of the crop diseases. The present study is an attempt to assess the role of weather parameters on stripe rust of barley disease development. The experiment was conducted on susceptible barley variety RD 2035 grown under five different dates of sown conditions at Rajasthan agricultural research institute, Durgapura (Jaipur) during 2016-17 and 2017-18. The weather factors (temperature, relative humidity, rainfall and sunshine hours) imparted an important role in the progression of stripe rust. Significant variations in AUDPC were observed among the crop planted at five different dates and the partial correlation was indicated that the weather factors positively correlated with the disease severity in all the planting dates. In the multiple linear regressions, the coefficient of determination was ranged from 0.59-0.77 which shows 59-77 per cent disease severity under influence of six meteorological factors. The normal sown crops were more vulnerable to stripe rust as compared to early and late sowing crops.

Keywords: AUDPC, barley, correlation, stripe rust, *Puccinia,* weather

Introduction

Barley (*Hordeum vulgare* L.) is an important coarse cereal crop of India, being grown in northern plains as well as in northern hills, mostly under rainfed or limited irrigation condition on poor to marginal soils. Sowing date is one of the most important factor which influence the yield potential of any crop under given set of conditions (Dhillon and Uppal, 2019) [5]. Barley is grown in more than hundred countries (Sarkar *et al*., 2014) [18]. Barley production has been estimated at 1590 thousand tons from 618.4 thousand ha area with an average national productivity of 25.73 q/ha. In India, Rajasthan is the largest state having >52% in production and 46% area followed by Uttar Pradesh. (IIWBR, 2019-20) [10]. Stripe rust caused by *Puccinia striiformis* f. sp. *hordei* is a major biotic factor which limits barley production especially in the northern western plains and northern hills of India (Verma *et al*., 2018) [24]. Historically stripe rust was commonly prevalent in cool and moist seasons. But in recent years, stripe rust is emerging as a serious threat in warmer areas where the disease was previously considered unimportant or absent due to movement of new aggressive strains of stripe rust which have ability to adopt higher temperature into non-traditional areas (Hovmoller *et al*., 2008) [8]. Many field crops can escape various diseases with the shifting of sowing time (Sud and Singh, 1984) [22]. Gradual increase in disease severity along with the advancement of sowing dates resulted into reduction in yield. This is probably because of the change in environmental condition, which might be congenial for disease development. Therefore, under epidemic conditions and non availability of resistant varieties, cultural practices is the only option in reducing rust severity as a component in integrated management of the disease. There is very little information published on the different date of sowings and meteorological parameters to manage barley stripe rust in India.

Material and Method

The experiments were laid out in completely randomized design (CRD) with four replications during *Rabi* season 2016-17 and 2017-18 in cage house under artificial rust inoculation conditions. The seeds of susceptible cultivar RD 2035 were sown by staggered sowing at 10 days interval initiated from 30th October, 10th Nov. 20th Nov., 30th Nov. and end with 10th

December in 25 cm earthen pots. The inoculum suspension was prepared by suspending the mixed pathotypes of PSH in sterile distilled water (95ml) in which 5ml of Tween-20 was added and shaked vigorously for uniform mixing of PSH pathotypes. Prior to inoculation, the seedlings were sprayed with fine mist of distilled water followed by smooth rubbing of leaves by fingers to disturb the wax layer and to open the stomata of leaves. In the periphery of the experiment, the susceptible infector rows were grown and artificially inoculated with mixture of races (G, M, 24 & 57) of stripe rust using spray and dusting methods. The twenty five days old plants of each sowing date was inoculated with mixed pathotypes of PSH. After inoculation, plants were misted again with hand sprayers and kept in saturated moist cloth chamber for 48 hours. After that regular mist-sprays of water were applied for creating optimum humidity in the pots (5 times per day). The effect of different epidemiological factors *viz*., maximum, minimum and average temperature (^{0}C), maximum, minimum and average relative humidity (%), rainfall (mm), sunshine hours (hrs/day) on the development of stripe rust was studied with the barley plants sown on different dates. The metrological data were collected from Agro-meteorological observatory, Rajasthan Agricultural Research Institute, Durgapura. Area under the disease progress curve (AUDPC), which is a better indicator of disease expression over time (Vander der Plank, 1963 [23]; Chaurasia *et al*. 1999) [2] was calculated on the basis of rust score recorded at weekly interval according to the formula suggested by Milus and Line (1986) [13].

$$AUDPC = [N_1(X_1 + X_2)/2] + [N_2(X_2 + X_3)/2] + [N_2(X_3 + X_4)/2]$$

Where: X_1, X_2, X_3, − the rust intensities recorded on the first, second and third; N_1 − the interval day between X_1 and X_2, and N_2 – the interval day between X_2 and X_3.

Correlation- Let Y, X_1 and X_2 be three variables, the correlation between the two variables Y and X_1 after removing the liner effect of variable X_2 is called the partial correlation, denoted by the symbol $r_{Y\,1,\,2}$ and is estimates as follows:

$$r_{Y1.2} = \frac{r_{Y1} - r_{Y2}r_{12}}{\sqrt{(1 - r_{Y2}^2)(1 - r_{12}^2)}}$$

Multiple linear regressions- Multiple regression of Y on X's is $Y= \beta_0+ \beta_1X_1+\beta_2X_2+\ldots+ \beta_6X_6$

Suppose X_1, X_2,… X_6 are the cause of variation (meteorological parameters) in Y (predicted disease severity) then in the model β_0= Intercept, β_1 to β_6 = Regression coefficients. X_1 to X_6 = Meteorological parameters, X_1 = Maximum temperature (ºC), X_2 = Minimum temperature (ºC), X_3 = Relative humidity (%) morning, X_4 = Relative humidity (%) evening, X_5 = Rainfall (mm) and x_6 = Duration of sunshine (hrs/day).

The inoculated plants were monitored regularly starting from last week of November to observe the initial symptoms of PSH. Disease severity (per cent infection) was recorded by modified Cobb's scale (Peterson *et al*., 1948) [15] on randomly tagged plants, with the appearance of symptoms. The severity of stripe rust was recorded on weekly interval between 48th Standard Meteorological Week (SMW) to 10th SMW during both the years.

Results and Discussion

The results of two consecutive years have been described in Table 1 to 6. Out of five sowing dates the lowest Area under disease progress curve value was shown by 10 December followed by 30 November in both the year of studies and found statistically similar during 2016-17 and 2017-18. The area under disease progress curve also different from October 30, November 10, 20, 30 and December 10. The AUDPC is a quantitative measure of disease intensity with time. It is used in plant pathology to indicate and compose level of resistance to disease among, effect of weather factors and different date of sowing. Lower AUDPC represented slower disease progression and the high AUDPC represents faster disease progression. Overall, both the seasons were normal but rainfall during the crop season 2016-17 was reasonably distributed and 27.7 mm higher than during 2017-18. Considerable variations were noticed in both AUDPC with plants sown on five different dates on stripe rust development. Recent devastating epidemics have occurred in warmer areas where the diseases was previously infrequent or absent (Hovmoller *et al*., 2010; Mboup *et al*., 2009) [9, 11].

In case of first date of sowing, primary infection appeared in 49th SMW (3rd Dec. 2017 and 9th Dec. 2017 respectively) and AUDPC value were 5.2 and 16.8 both the seasons, respectively. Second date of sowing, period between 8th to 10th SMWs the AUDPC values ranged from 315.3 to 328.2 which were higher as compared to first date of sowing according to Wanyera *et al*. (2009) [25] the cool weather conditions, frequent rainfall during the growth seasons of crop which is highly favourable for yellow rust infection and development.

The maximum disease progress was noticed in the plants sown on third date of sowing as compared to other dates of sowing. There was rainfall (22.4 mm) and favorable mean temperature (14-20.45 °C), for rust development during 3rd to 8th SM weeks which end result an abrupt increased in AUDPC ranging from 146 to 381.1. Thereafter, the disease progression was constantly increased in the 9th and 10th SM weeks with AUDPC value 401.8 and 423.0 respectively. Study supported by Fender (2004) [6] the disease severity of cereal rust highest in early-planted crop and delay of autumn planting date may provide a useful cultural control method of rust pathogen.

Similarly, during second season, AUDPC value was 11.9 (51 SMWs). Thereafter, gradual increase in disease progress during 2nd to 4th SMWs with AUDPC ranging from 119.8 to 189.1. The disease rapidly increased in 5th to 7th SMWs AUDPC ranged from 246.9 to 325.0 due to favorable weather condition for rust development. Last three SMWs (8-10) AUDPC value of 358.7. Other workers, Gupta *et al*. (2013) [7] recorded that the highest disease prevalence due to conducive environmental conditions coupled with virulent pathotypes outbreak. The fourth sowing was done on 30th Nov. and initial AUDPC value was 6.65 and 14.0 (SMW-1) during both the season respectively. At last the AUDPC was calculated as 220.8 and 237.1 during 9th and 10th SM weeks respectively. In second season rust progression higher AUDPC was recorded in the 8th SMW (204.3) followed by 9th and 10th ranging from 214.9 and 220.5 respectively. The area under disease progress curve (AUDPC) was maximum in susceptible and zero in resistance verities Sandhu *et al*. (2016) [17].

The last date of sowing strip rust appeared late due to cool weather conditions during SMW 1st - 3rd resulting in longer incubation period. During this DOS the rust progression was less as compared to four other dates of sowing. The AUDPC in 4th SM week was 6.3 and after that in 5th to 10th SM weeks slow rust progression were noticed ranging from 14.4 to 172.1. Similar results found in second cropping season the AUDPC range 8.8-37.9 in the 2nd and 3rd SMWs and thereafter it increased from 74.2 to 174.8 in between 4th to 7th SMWS. The disease progress was very slow in last 8th to 10th SMW which ranged between 187.1- 199.0 The optimum temperature for development of stripe rust in plants is 13-18°C. Under optimum conditions, the time from inoculation to sporulation is 12-13 days (Line, 2002; Davis & Jackson, 2002) [3, 4].

During the first cropping season 2016-17, the period between 4th to 8th SM weeks was found most favorable with minimum (17.2), maximum (20.45) average temperature and rainfall (22.4 mm) for stripe rust development with high AUDPC values. During the second cropping season 2017-18, the period between 4th to 7th SMWs (22nd Jan. to 12nd Dec.) was found most favourable with minimum (15.95 °C), maximum (19.2 °C) average temperature and rainfall (1.4 mm) for stripe rust development with high AUDPC (Table 1 and 3). Murray *et al*. (2005) [14] observed that the infection efficiency of rust pathogen affected by meteorological parameters. Temperature and humidity play an important role in disease infection. Infection requires high humidity for 4 to 6 hr at 10 to 15 °C. Infection seldom occurs below about 2 °C and ceases above 23 °C.

Correlation analysis of various epidemiological factors with the severity of stripe rust in five different DOS during 2016-17 and 2017-18 were performed to know the any significant association among them. Correlation analysis of per cent rust severity with weather parameters indicated that maximum (29.9 ^{0}C) and minimum (5.7 ^{0}C) temperature and sunshine hours had positive but non-significant correlation with the disease severity. However, statistically analysis of rainfall showed positive correlation but non-significant with the disease severity at all different dates of sowing during 2016-17 (Table 2). Work supported by Singh *et al.* (2007) [19] relationship between weather parameters and occurrence of stripe rust, Maxi. and mini. Temp., wind speed, evaporation and sunshine hours showed positive correlation, whereas morning and evening relative humidity and rainfall showed negative correlation with stripe rust intensity. Perusal of the data presented in Table 5 indicated that under I, II and III DOS, the temperature (maximum and minimum) and sunshine hours had non-significant but positive correlation with the disease severity. In case of IV and V DOS indicated that the temperature (maximum and minimum) had positive significant correlation and sunshine indicated positive non significant correlation with disease severity. Salman *et al*. (2006) [16] reported that the stripe rust have been showing highly positive correlation with minimum temperature, relative humidity and rainfall.

Multiple linear regressions: - Perusal of the data presented in Table 3 and 6 indicated that coefficients of I to V DOS (R^2) were 0.71 to 0.75 and 0.59 to 0.77. It indicated that there was 71 to 75% influence of six meteorological factors and the remaining 25 to 29% variations were unexplained which showed that 71 to 75 per cent disease severity was depended on the meteorological factors taken into consideration during cropping season with all different dates of sowing.. which was in confirmation with the findings of others workers who reported that stripe rust severity had strong correlation with maximum temperature, minimum temperature and sunshine hours having 'R' value of 0.45, 0.3 and 0.47, respectively Ahmed *et al*. (2010) [1].

Table 1: Effect of epidemiological factors on the progression of stripe rust of barley with different date of sowing during *Rabi* 2016-17

Standard week	Dates of meteorological weeks	Temperature (^{0}C)			Relative Humidity (%)			Rainfall (mm)	BSH (hrs)	AUDPC* DOS**				
		Max.	Min.	Mean	Max.	Min.	Mean			30 Oct.	10 Nov.	20 Nov.	30 Nov.	10 Dec.
48	26.11.16 to 2.12.16	26.4	13.4	19.9	70	38	54	0.0	6.0	0	0	0	0	0
49	3.12.16 to 9.12.16	27.8	10.8	19.3	80	29	54.5	1.9	8.9	5.2	0	0	0	0
50	10.12.16 to 16.12.16	27.6	13.4	20.5	72	34	53	2.3	7.9	16.5	8.0	0	0	0
51	17.12.16 to 23.12.16	25.4	8.9	17.15	73	19	46	0.0	9.2	32.6	22.2	0	0	0
52	24.12.16 to 31.12.16	25.9	10.2	18.05	87	31	59	0.0	8.7	63.4	44.9	14.35	0	0
1	1.1.17 to 7.1.170	23.2	10.4	16.8	89	45	67	0.0	8.2	87.9	75.9	51	6.65	0
2	8.1.17 to 14.1.17	19.3	5.7	12.5	82	29	55.5	0.0	8.0	110.9	111.2	85.85	28.15	0
3	15.1.17 to 21.1.17	20.6	7.4	14.0	70	28	49	0.0	8.4	138.1	152.8	146	47.4	0
4	22.1.17 to 28.1.17	23.1	12.2	17.65	77	49	63	22.4	6.5	173.1	195	204.1	76.8	6.3
5	29.1.17 to 4.2.17	24.2	12.2	18.2	82	45	63.5	0.0	8.8	209.7	245.9	260.9	112.5	14.4
6	5.2.17 to 11.2.17	24.0	10.4	17.2	82	58	70	0.0	8.6	238.1	289	299.5	139.1	26.3
7	12.2.17 to 18.2.17	27.2	10.6	18.9	77	36	56.5	0.0	9.1	271.5	315.7	347.5	166.5	63.2
8	19.2.17 to 25.2.17	28.7	12.2	20.45	72	24	48	0.0	9.8	301.1	334.5	381.1	196.2	92.5
9	26.2.17 to 4.3.17	29.9	15.2	22.55	54	21	37.5	6.4	8.7	313.6	349.6	401.8	220.8	128.2
10	5.3.17 to 11.3.17	27.7	13.8	20.75	61	29	45	3.8	8.6	323.8	359.1	423.0	237.1	172.1

* AUDPC- Area under disease progress curve, Mean of four replications. ** DOS- Date of sowing, Observation started 7days after inoculation and at weekly intervals. 1st Sown- 30 Oct. 2016 2nd 10 Nov. 2016 3rd 20 Nov. 2016 4th 30 Nov. 2016 5th 10 Dec. 2016

Table 2: Correlation of epidemiological factors with the progression of stripe rust of barley during *Rabi* 2016-17

Epidemiological Factor	Temperature (^{0}C)		Rainfall (mm)	BSH (hrs)
	Max	Mini		
I DOS	0.16	0.26	0.17	0.36
II DOS	0.16	0.27	0.17	0.34
III DOS	0.21	0.33	0.19	0.32
IV DOS	0.30	0.40	0.17	0.32
V DOS	0.42	0.49	0.13	0.32

DOS – Dates of sowing

Table 3: Multiple linear regressions of epidemiological factors and stripe rust of barley during *Rabi* 2016-17

Date of sowing	Constant (a)	X_1	X_2	X_3	X_4	X_5	X_6	R^2
I DOS	-3.06	-3.76	2.90	-2.09	1.42	1.03	24.78	0.71
II DOS	3.51	-3.87	2.39	-2.70	1.98	1.11	28.63	0.73*
III DOS	-1.08	-3.68	2.73	-3.30	2.30	1.29	32.32	0.74*
IV DOS	-6.78	-1.20	1.39	-1.80	1.13	0.56	16.30	0.75*
V DOS	2.29	-0.40	1.52	-0.95	0.26	0.16	7.37	0.71

X_1 = Maximum temperature (ºC) X_2 = Minimum temperature (ºC)
X_3 = Relative humidity (%) morning X_4 = Relative humidity (%) evening
X_5 = Rainfall (mm) X_6 = Sun shine hours/day
R^2 = Coefficient of determination **significant

Table 4: Effect of epidemiological factors on the progression of stripe rust of barley with different date of sowing during *Rabi* 2017-18

Standard week	Dates of Meteorological weeks	Temperature (ºC)			Relative Humidity (%)			Rainfall (mm)	BSH (hrs)	AUDPC* DOS**				
		Max.	Min.	Mean	Max	Min.	Mean			30 Oct.	10 Nov.	20 Nov.	30 Nov.	10 Dec.
48	26.11.17 to 2.12.17	28.3	11.0	19.65	59	16	37.5	0.0	8.7	0	0	0	0	0
49	3.12.17 to 9.12.17	24.40	11.40	17.90	64	30	47.00	0.0	4.5	16.8	0.0	0.0	0.0	0.0
50	10.12.17 to 16.12.17	23.80	10.00	16.90	65	33	49.00	5.4	6.6	47.5	17.5	0.0	0.0	0.0
51	17.12.17 to 23.12.17	25.00	8.40	16.70	62	19	40.50	0.0	7.2	71.0	40.5	11.9	0.0	0.0
52	24.12.16 to 31.12.17	24.90	7.90	16.40	79	24	51.50	0.0	8.5	94.9	80.5	31.9	0.0	0.0
1	1.1.18 to 7.1.18	22.50	6.00	14.25	88	24	56.00	0.0	7.9	129.4	119.9	68.4	14.0	0.0
2	8.1.18 to 14.1.18	23.80	6.40	15.10	80	18	49.00	0.0	9.1	157.0	169.6	119.8	43.6	8.8
3	15.1.18 to 21.1.18	26.70	8.10	17.40	71	18	44.50	0.0	8.9	173.3	195.7	145.6	76.4	37.9
4	22.1.18 to 28.1.18	23.90	8.00	15.95	84	29	56.50	1.4	8.2	191.5	211.9	189.1	104.6	74.2
5	29.1.18 to 4.2.18	27.50	10.90	19.20	61	19	40.00	0.0	8.8	206.0	231.0	246.9	138.7	125.1
6	5.2.18 to 11.2.18	24.60	9.80	17.20	50	19	34.50	0.0	6.6	242.8	273.2	296.5	167.6	160.4
7	12.2.18 to 18.2.18	25.80	10.00	17.90	69	23	46.00	0.0	8.4	266.9	307.6	325.0	186.0	174.8
8	19.2.18 to 25.2.18	31.10	14.60	22.85	65	22	43.50	0.0	8.7	278.4	315.3	342.3	204.3	187.1
9	26.2.18 to 4.3.18	31.90	16.40	24.15	63	21	42.00	0.0	8.6	287.8	323.2	350.7	214.9	193.2
10	5.3.18 to 11.3.18	31.50	15.40	23.45	53	17	35.00	0.0	9.3	292.3	328.2	358.7	220.5	199.0

* AUDPC- Area under disease progress curve, Mean of four replications.
** DOS- Date of sowing, Observation started 7days after inoculation and at weekly intervals
1st Sown- 30 Oct. 2017 2nd 10 Nov 2017 3rd 20 Nov 2017 4th 30 Nov 2017 5th 10 Dec 2017

Table 5: Correlation of epidemiological factors with the progression of stripe rust of barley during *Rabi* 2017-2018

Epidemiological Factor	Temperature (ºC)		Rainfall (mm)	BSH (hrs)
	Maximum	Minimum		
I DOS	0.48	0.39	-0.23	0.48
II DOS	0.49	0.38	-0.26	0.51
III DOS	0.53	0.47	-0.22	0.44
IV DOS	0.58*	0.55*	-0.17	0.41
V DOS	0.56*	0.59*	-0.13	0.34

DOS- Dates of sowing, *Significant at 5%

Table 6: Multiple linear regressions of epidemiological factors and stripe rust of barley during *Rabi* 2017-18

Date of sowing	Constant (a)	X_1	X_2	X_3	X_4	X_5	X_6	R^2
I DOS	106.72	-14.80	13.37	-0.79	1.89	-9.34	24.92	0.59
II DOS	120.35	-17.92	15.89	-1.12	2.57	-12.40	31.67	0.62
III DOS	154.91	-21.65	19.62	-1.70	3.47	-15.34	37.17	0.70
IV DOS	69.02	-11.57	11.02	-1.13	2.35	-8.95	21.56	0.72
V DOS	69.97	-11.04	10.06	-1.43	2.94	-9.67	21.49	0.77*

X_1 = Maximum temperature (ºC) X_2 = Minimum temperature (ºC)
X_3 = Relative humidity (%) morning X_4 = Relative humidity (%) evening
X_5 = Rainfall (mm) X_6 = Sun shine hours/day
R^2 = Coefficient of determination * Significant

Conclusion

Maximum disease severity was observed in timely sown crop 10th -20th November (AUDPC: 323.8 - 423) while, minimum disease severity was recorded in late sown crop on 10th December (AUDPC: 172.1). There was sharp increase in AUDPC between 1 to 8th standard meteorological week due to favorable weather conditions for the stripe rust. The development of stripe rust in barley was influenced by various epidemiological factors. Minimum and maximum temperature, rainfall and bright sunshine hours showed positive, while maximum, minimum and mean relative humidity showed negative correlation with rust progression. The coefficient of determination ranged from 0.59 - 0.77 which indicated significant relationship between stripe rust progression and epidemiological factors with all the planting dates. Thus it is recommended that barley may be sown before November 20 to avoid losses caused by stripe rust disease.

References

1. Ahmed S, Afzal LRN, Iqbal Z, Akhtar N, Iftkar Y, Kamran M. Prediction of yield losses in wheat (*Triticum aestivum*) caused by yellow rust in relation to epidemiological factors in Faisalabad. Pak. J. Bot 2010;42(1):401-407.
2. Chaurasia S, Joshi AK, Dhari R, Chand R. Resistance to foliar blight of wheat: A search. Genetic Research Crop Evol 1999;46:469-475.
3. Chen X, Line RF. Identification of genes for resistance to *Puccinia striiformis* f. sp. *hordei* in 18 barley genotypes. Euphytica 2002;129:127-145.
4. Davis RM, Jackson LF. UC IPM Pest Management Guidelines: Small grains stripe rusts of wheat and barley, pathogen: *Puccinia striiformis*. UCANR Publication 3466 at http;//axp.ipm.ucdavis.edu/PMG/r73010051 1.html 2002
5. Dhillon BS, Uppal RS. Influence of cutting management on photosynthetic parameters, heat use efficiency and productivity of barley (*Hordium vulgare* L.) under variable sowing dates. J. of Agrometeorol 2019;21(1):51-57.
6. Fender PWF. Effect of autumn planting date and stand age on severity of stem rust in seed crops of perennial rye grass. Plant Disease 2004;88:1017-1020.
7. Gupta PK. Barley Breeding. In: Yadav, M.M., Singh, R., Pal, S., Singh, P., Prakash, H.G., Singh, N.B., Singh, D.P., Pandey, R.K., Gupta, P.K. and Bahar, J. (eds.), Highlights of Wheat and Barley Research. C.S.A. University Publication in Collaboration with DWR (ICAR), Kanpur, India 2013,67-71p.
8. Hovmoeller MS, Yahyaoui AH, Milus EA, Justesen AF. Rapid global spread of two aggressive strains of a wheat rust fungus. Mol. Eco 2008;17:3818-3826.
9. Hovmoeller MS, Walter S, Justesen AF. Escalating threat of wheat rusts. Science 2010,329,369.
10. IIWBR. Annual Report 2019-20, ICAR - Indian Institute of Wheat and Barley Research, Karnal-132001, Haryana, India 2019-20.
11. Mboup M, Leconte M, Gautier A, Wan AM, Chen WQ, de Vallavielle-Pope C, Enjalbert J. Evidence of genetic recombination in wheat yellow rust population of Chinese over- summering area. Fungal Genet. Biol 2009;46:299-307.
12. Ihsanul Huqa M, Nowsher Ali Khan AZM. Effect of Sowing Dates on the Incidence of Stemphylium Blight of Lentil During 1998-2001 Bangladesh J. Sci. Ind. Res 2007;42(3):341-346.
13. Milus EA, Line RF. Gene action for inheritance of durable, high– temperature, adult plant resistances to stripe rust in wheat. Phytopathology 1986;76:435-441.
14. Murray G, Wellings C, Simpfendorfer S. Report on Stripe Rust: Understanding the disease in wheat. New South Wales Department of Primary Industries 2005,1-12p.
15. Peterson RF, Campbell AB, Hannah A. A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. Canadian Journal Research 1948;26:496-500.
16. Salman A, Khan MA, Hussain M. Prediction of yield losses in wheat varieties/lines due to leaf rust in Faisalabad. Pakistan Journal Phytopathology 2006;18(2):178-182.
17. Sandhu, Kaur Sarabjot, Dhaliwal LK, Pannu PPS. Role of microclimate in management of yellow rust (*Puccinia striiformis* f. sp. *tritici*) of wheat (*Triticum aestivum*) under Ludhiana conditions. Indian Journal of Agricultural Sciences 2016;86(7):930-4.
18. Sarkar B, Sarkar A, Sharma RC, Verma RPS, Sharma I, Genetic diversity in barley (*Hordeum vulgare* L.) for traits associated with feed and forage purposes. Indian Journal of Agriculture Science 2014;84(5):102-107.
19. Singh Raj, Singh Diwan, Rao VUM, Karwasra SS, Beniwall MS, Singh Ram *et al*. Role of weather variable in development of stripe rust of wheat under Hisar conditions. Haryana agric. Univ. Journal Research 2007;37:9-13.
20. Singh J, Lal C, Kumar D, Khippal A, Kumar L, Kumar V *et al*. Widening the Genetic Base of Indian Barley Through the Use of Exotics. International Journal of Tropical Agriculture 2016,34.
21. Singh TB, Tewari AN. The role of weather conditions in the development of foliar diseases of wheat under tarai conditions of north western India. Plant Disease Research 2001;16(2):173-178.
22. Sud VK, Singh BM. Effect of sowing dates and row spacing on the development of leaf spot *(Cercospora canescens)* on Urdbean. Indian Phytopath 1984;37:288-293.
23. Vander der Plank JE. Plant diseases. Epidemic and Control. Academic Press, New York–London 1963.
24. Verma RPS, Selvakumar R, Gangwar OP, Shekhawat PS, Subhash CB, Bhardwaj SC *et al*. Identification of additional sources of resistance to *Puccinia striiformis* f. sp. *hordei* (PSH) in a collection of barley genotypes adapted to the high input condition, Journal of phytopathology 2018;166:355-364.
25. Wanyera R, Macharia JK, Kilonzo SM, Kamundia JW. Foliar fungicides to control wheat stem rust race TTKS (Ug99) in Kenya. Plant Disease 2009;93:929-932.
26. Wellings, Colin, Plant Health Australia. Contingency plan for barley stripe rust (*Puccinia Striiformis* f. sp. *hordei*): www.planthealthaustralia.com.au 2010.