Int.J.Curr.Microbiol.App.Sci (2021) *10*(05): 463-471

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 10 Number 05 (2021)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2021.1005.054

Role of Weather Factors and Wheat Varieties on the Occurrence of Leaf Rust of Wheat in Satna, M.P. India

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Keywords

Wheat; Leaf rust; Temperature; Rainfall; RH; Varieties; Resistance

Article Info

Accepted:
14 April 2021
Available Online:
10 May 2021

A B S T R A C T

Weather data of February (III & IV weeks) and March (I, II & III weeks) during two cropping seasons (2018-19 and 2019-20) on the incidence of LR of wheat were recorded from Satna, M.P. to find out the effect of weather factors on disease development, its intensity and response of wheat varieties against LR under these weather factors. In cropping season 2018-19 (Feb. & Mar. 2019) weather remained unfavourable (mean max., mean min. & average RH of Feb. were 44.57, 18.36 & 31.46% respectively & of Mar. were 49.05, 31.14, & 40.09% respectively) and rainfall and cloudiness were very low for development of LR therefore, disease was not occurred. In cropping season 2019-20 (Feb. & March 2020) mean max., mean mim. & average RH of Feb. were 85.64, 39.21 & 62.42% respectively & of Mar. were 84.66, 39.09, & 61.87% respectively were favourable for LR disease development therefore, disease was occurred in most of the varieties grown in the experiment. In the present study there were not more differences in mean mim., mean max. and average temp. (Feb. & March) during both cropping seasons. Total rainfall in2018-19 (Feb & March) was only 2.75mm. while in 2019-20 (Feb. & March) it was 41mm, very high as compared to Feb. & March 2019 which increased the total RH for disease development. The most significant effect on the development of LR on wheat was high RH, amount of rainfall and number of days with precipitation during mid Feb. to mid-March. It was also observed that most of LR resistance was broken down by the favourable weather conditions. Only HI 1605, JW 3288, HI 1531, HI 1500, HI 8498, HI 8713, MP 1142, HD 2864, HI 1500, HI 8627, GW 322 and Sonalika were found resistant.

Introduction

Better crop production is not possible without favorable agrometeorological factors (temp., RH, rainfall, light, wind velocity etc.) even agronomic practices like - soil, manure & fertilizers, crop variety, time & spacing, irrigation, weed management, crop protection etc. remain optimum. Meanwhile, "Agriculture is said to be a grate gamble" due to the complexity of agrometeorological factors. Farmers face a lot of problems due to

these meteorological factors in crop production.

Environment plays an important role in disease development while soil and weather conditions influence the seasonal development and geographical distribution of plant diseases. The effects of environmental factors on plant diseases have been reviewed by Colhoun (1973). Further the influence of environment on the development and the control of disease have also been reviewed by McCartney in 1997. Host (plant species) is another important factor in development and control of plant diseases which allow or reject the pathogen to harbor on or in it for completion of its life cycle. Human being is not able to control the weather and dispersal of pathogen through wind and cyclonic rain but the susceptibility of host against any pathogen can be controlled through development of resistance against a particular pathogen.

Wheat (*Triticum aestivum* L.) is the plant ever to be cultivated and plays a key role in Man's economic and social development. Many wheat high yielding varieties which have been performing better in response to yield for many years suddenly fail due to adverse environmental/weather conditions. Though many biotic stresses obstruct wheat production, out of which rust diseases are best known as their devastating and widespread nature because these have caused epiphytotic conditions in India which have created famines in the country (Sleeman 1839; Joshi et.al. 1970; Joshi 1976; Joshi et.al., 1984a, 1985). However, the rust pathogens continue to affect production through the occurrence of new virulent races and adverse meteorological conditions that have led to the discontinuance of important varieties. Depending on the direction of wind spread of uredospores in each cropping year, wheat growing areas of the World are clustered in nine epidemiological regions. India is also one of these nine regions of leaf rust (LR) epidemics (CABI, 2012). In relation to meteorological factors, cyclonic storms from the way of Bengal in October and November, bring heavy rain in the central districts of Tamil Nadu, Andhra Pradesh and Orissa every year which carry uredospores of black and brown rusts of wheat from the southern hills to the central province of the country (Joshi, et. al. 1974; Nagarajan & Singh, 1973, 1974; Joshi et.al. 1985; Bahadur, *et al.,* 1994).Instead of dispersal of LR the amount of precipitation and number of rainy days also play an important role in disease development (Nagarajan and Joshi,1978a; Singh & Tiwari,2001). The requirement of minimum, maximum and optimum temperatures for the germination of uredospores, growth of germ tubes, formation of appressoria, penetration and formation of sub stomatal vesicles have been best studied by many plant pathologists (Stubbs *et al*., 1986; Stuckey & Zadoks, 1989; Singh *et al*., 2002; Riaz *et al*., 2013; Marsalis and Goldberg 2017). Leaf wetness and latent period is another factor for LR disease development (Stuckey & Zadoks, 1989; Riaz *et al*., 2013; Marsalis and Goldberg 2017). Number of hours with temperature between 5 to 25°C and relative humidity >87% are highly correlated and predicts LR infections with 89% accuracy.

Host (wheat varieties) is another important factor in the development of LR disease. Many resistant/tolerant wheat genotypes (varieties) have been developing against LR disease of wheat since 1960s for management of this devastating disease but due to continuous evolution of new races of the fungus, *Puccinia recondite* Rox. Ex Desm. and favourable weather conditions for the fungus (temp., relative humidity and rainfall during crop season) this resistance is broken down (Muhammad *et al*., 2015). The objective of this study was to identify the key weather-disease links in Satna, M.P. This study was

also attempted by employing effort that how LR epiphytotic correlated with weather factors.

Materials and Methods

Fifty notified, unnotified and local wheat varieties were collected from different sources. Seeds of collected varieties were sown manually on 15th&25th Nov. 2018 and 2019 respectively in the experimental field of plant breeding, AKS University, Satna. Each variety was sown in 2×10 m size plot by maintaining isolation distance of 1 m. The row-to-row distance was kept 25 cm and plant to plant distance 5cm. Recommended agronomic practices were followed to raise the crop as per the Vindhyanchal region. The objectives of the experiment were to determine the role of weather factors (temp., relative humidity and winter rainfall) and existed wheat varieties in the occurrence of LR disease in Vindhyanchal region and to determine the interaction of weather and existed wheat varieties in development of LR disease in the region. The experimental study was carried out during 2019-2020 crop season at the altitude above the sea level 315 m in the natural field conditions. The annual average rainfall is 1140 mm. Nitrogen and phosphorus were applied at the rate of 100 kg/ha. and 80 Kg/ha. respectively. The soil of experimental field is calcareous with pH 7.5. The crop was irrigated three times according to critical stages of wheat except rainfall during the cropping season. The varieties used in the experiment were enlisted on the basic of year of release. Natural disease infection was observed after first sign of disease to till the dough stage of the crop (from first week of March to third week of March). The incidence of wheat LR can be calculated arbitrary according to Cobb, 1892; Horsfall and Barratt, 1945; Peterson *et al*., 1948 and Chester, 1950. Here I have estimated the incidence of LR as per Horsfall and Barratt, 1945 who gave 12-grade scale (1=0%, 2=0-3%, 3=3-6%, 4=6-12%, 5=12-25%, 6=25-50%, 7=50-75%, 8=75-87%, 9=87-94% 10=94-97%, 11=97-100% and 12=100%) and took into consideration the fact that the grades detected by human eye are approximately equal divisions on a log scale. The disease incidence was observed after first sign of disease (10 days after first winter rainfall i.e., first week of March) to till the dough stage of the crop (third week of March) in both cropping seasons (2018-19 & 2019-20). All wheat varieties used in the experiment were tabulated on the basis of year of release and status of resistance (Table 2). Uredospores were observed by the compound microscope with 10X and 45X magnifications using cotton blue as stain. Since, the LR of wheat has intimate relation with weather factors (temperature, relative humidity and winter rainfall)which were obtained from observatory of AKS University and were calculated as mean; maximum, minimum temperatures and relative humidity (RH) of February (third and fourth weeks) and March (first, second & third weeks) 2019 and 2020 (Table 1). These weather data were used in the establishment of relationship with development of LR disease by Nagarajan and Joshi (1978a); Stubbs *et al*., (1986); Stuckey & Zadoks (1989); Singh *et al*., (2002); Riaz, *et al*., (2013); Marsalis and Goldberg (2017).

Results and Discussion

The disease was diagnosed on the basis of characteristics symptoms of LR that the uredia were confined only to leaves not on sheath and stem. They were not in rows or strips. Uredia were round to slightly oblong, brown and were irregularly scattered and some uredia were also in clusters only on the leaf blade (Fig. 1). The uredospores were brown to bright orange coloured, spherical with minutely echinulate walls (Fig. 2). The telia were not developed in most affected varieties but in few infected

varieties they were developed on the lower surface of the leaf blade which were small, linear, dull black and covered by epidermis (Fig. 3). Weather factors (temperature, humidity and winter rainfall) played a crucial role in the incidence of LR. The disease was not observed during cropping season 2018-19 due to unfavourable weather factors for the disease while it was observed during cropping season 2019-20 due to favourable weather for the disease development (Table 1).

In present Rabi crop season (2019-20) weather conditions such as temperature and humidity (mean maximum, mean minimum & average) in February and March months remained optimum due to occasional winter rainfall for the development of LR (Table 1). Winter rainfall in February due to western disturbance brought the uredospores of *Puccinia recondita* Rox. Ex Desm. in the Vindhyachal region of MP. Occasional rainfall in March month (Table 1) predisposed the wheat crop and LR fungus for disease development.

These weather conditions became favourable for growth of germ tubes, formation of appressoria, penetration, formation of sub stomatal vesicle and pustules formation. In these favourable weather conditions, the LR was developed in most wheat varieties (Table 2) even in the varieties which were characterized as resistant against LR at the time of release by the plant breeders and have been performing better for last many years due to unfavourable weather for disease development. In present study it was also found that most of low yielding varieties like HI 1605, JW 3288, HI 1531 and HI 1500 were either immune or very resistant while most of high yielding varieties were found either moderately susceptible or very susceptible (Table 2). Weather data in table 1 show that in February 2019 the average relative humidity (III & IV weeks) has been remained very low (31.46%) due to clear sky after winter rainfall (2.75mm) in III week, which was unfavourable for germination of uredospores, formation of appressoria and penetration while average temp. (20.50°C) was suitable (15-20°C; Singh *et al.,* 2002)for overall development of LR fungus. In March 2019 average relative humidity and average temp. were remained 40.09% and 24.90°C(Table 1) respectively which were also not suitable for pustule formation. Therefore, LR was not observed in wheat crop during 2018-19 in Satna district of M.P. In February 2020, total winter rainfall (21mm) from western disturbance has occurred in third week on two consecutive days (20 and 21Feb.) which could bring uredospores of LR. The total period of leaf wetness has also increased for 4-5 days due to cloudiness after rainfall. In fourth week of February 2020 mean mim., mean max. and average temp. were 15.43°C, 28.28°C,21.85°C respectively and Mean max. and average RH were 89.57% 64.14% respectively (Table 1) became suitable for growth of germ tube, appressoria formation and penetration (according to Singh *et al.,* 2002).Further, the weather of March 2020 (table1) i.e., temp. and RH became optimum for pustule formation and sporulation. Therefore, LR was observed in most of the wheat varieties (Table 2) grown in the experimental field.

LR caused by *Puccinia recondita* Rox. Ex Desm.is very destructive pandemic disease of wheat crop which not only reduce the crop yield but also responsible for socio-economic instability. The present study was conducted to study the role of weather factors and to work out the relationship of LR disease development with the weather factors.

Relative humidity, air temperature and precipitation are critical causative factors to the infection and progress for LR in winter wheat (Junk *et al.,* 2016).

Table.1 Meteorological data of February and March 2019 and 2020

S. No.	Month & year		Mean min.Temp	Mean max.Temp	Average Temp.	Mean mim. RH	Mean max. RH	Average RH	Rainfall (in mm.)
1.	February 2019		**11.56°C**	**29.44°C**	**20.50°C**	**18.36%**	**44.57%**	**31.46%**	**2.75**
		III Week	11.96	28.30	20.13	11.28	28.57	19.92	2.75
		IV Week	11.16	30.59	20.88	25.45	60.57	43.00	-
2.	March 2019		**18.64°C**	**31.15°C**	**24.90°C**	**31.14%**	**49.05%**	**40.09%**	-
		I Week	17.31	28.23	22.77	26.30	55.47	40.88	-
		II Week	18.51	31.95	25.23	34.36	46.46	40.41	-
		III Week	20.12	33.27	26.70	32.78	45.22	39.00	-
3.	February 2020		**13.93°C**	**28.64°C**	**21.28°C**	**39.21%**	**85.64%**	**62.42%**	**21**
		III Week	12.43	29.00	20.71	31.71	81.71	56.71	21
		IV Week	15.43	28.28	21.85	46.71	89.57	68.14	-
4.	March 2020		**16.52°C**	**29.85°C**	**23.18°C**	**39.09%**	**84.66%**	**61.87%**	**20**
		I Week	16.71	30.42	23.56	46.85	87.28	67.06	1
		II Week	17.00	29.43	23.21	38.00	87.00	62.50	19
		III Week	15.85	29.71	22.78	32.42	79.71	56.06	-

Table.2 Wheat varieties evaluated against leaf rust disease

S. No.	Name of varieties	Year of release Source- iiwbr.org.in	*Disease incidence		**
			2018-19	2019-20	
1.	HI 1605 (PusaUjala)	2017	1 (0%)	5 (12-25%)	R
2.	HD 4728 (PusaMalwi)	2016	1 (0%)	1 (0%)	R
3.	HI 8737 (Pusa Anand)	2015	1 (0%)	1 (0%)	R
4.	JW 3382	2015	1 (0%)	4 (6-12%)	T
5.	HI 8713 (Pusa Mangal)	2013	1 (0%)	2 (0-3%)	R
6.	HD 2967	2011	1 (0%)	6 (25-50%)	R
7.	JW 3288	2011	1 (0%)	2 (0-3%)	T
8.	GW 3288	2010	1 (0%)	4 (6-12%)	R
9.	JW 3211	2010	1 (0%)	6 (25-50%)	R

10.	MP 1201	2010	1 (0%)	6 (25-50%)	R
11.	MP 1215	2010	1 (0%)	5 (12-25%)	R
12.	JW 1203	2009	1 (0%)	4 (6-12%)	-
13.	HD 2932	2008	1 (0%)	7 (50-75%)	R
14.	MP 1202	2008	1 (0%)	7 (50-75%)	-
15.	HI 8627 (Malav Kirti)	2007	1 (0%)	2 (0-3%)	R
16.	GW 366	2007	1 (0%)	1 (0%)	R
17.	MP 1142	2007	1 (0%)	3 (3-6%)	-
18.	HI 1531 (Harshita)	2006	1 (0%)	1 (0%)	R
19.	Raj 3777	2006	1 (0%)	5 (12-25%)	-
20.	HD 2864 (Urja)	2005	1 (0%)	2 (0-3%)	HR
21.	JW 3020	2004	1 (0%)	5 (12-25%)	R
22.	HI 1500 (Amrita)	2003	1 (0%)	2 (0-3%)	R
23.	MP 4010	2003	1 (0%)	4 (6-12%)	R
24.	GW 322	2002	1 (0%)	2 (0-3%)	HR
25.	MP 1106	2002	1 (0%)	5 (12-25%)	R
26.	HI 1418	2000	1 (0%)	3 (3-6%)	R
27.	HI 1454	2000	1 (0%)	6 (25-50%)	R
28.	HI 8498 (Malav Shakti)	1999	1 (0%)	1 (0%)	R
29.	UP2425	1999	1 (0%)	7 (50-75%)	R-YR
30.	JW 273	1998	1 (0%)	6 (25-50%)	R
31.	JWS 17	1997	1 (0%)	7 (50-75%)	R
32.	Raj 3765	1996	1 (0%)	3 (3-6%)	-
33.	PBW 343	1996	1 (0%)	7 (50-75%)	-
34.	UP 2338	1995	1 (0%)	7 (50-75%)	-
35.	HI 784	1984	1 (0%)	3 (3-6%)	R
36.	Lok 1	1982	1 (0%)	6 (25-50%)	R
37.	WH 147	1978	1 (0%)	8 (75-87%)	-
38.	C 306	1969	1 (0%)	6 (25-50%)	S
39.	Sonalika	1969	1 (0%)	2 (0-3%)	R
40.	UnnatHalna	UN	1 (0%)	9 (87-94%)	-
41.	MP 1132	UN	1 (0%)	5 (12-25%)	-
42.	MP 1133	UN	1 (0%)	8 (75-87%)	-
43.	JW 1105	UN	1 (0%)	8 (75-87%)	-
44.	JW 2030	UN	1 (0%)	4 (6-12%)	-
45.	Research Thunder	UN	1 (0%)	4 (6-12%)	-
46.	HIPW 168	UN	1 (0%)	8 (75-87%)	-
47.	JW 322	UN	1 (0%)	6 (25-50%)	-
48.	Paigambari	Local	1 (0%)	7 (50-75%)	-
49.	Bansi	Local	1 (0%)	4 (6-12%)	-
50.	Sharwati	Local	1 (0%)	7 (50-75%)	-

*Estimated disease incidence ** Leaf rust resistance status at the time of variety release, R = Resistant, HR = Highly Resistant, YR = Resistant to Yellow Rust, S = Susceptible, VR= Very Resistant, MR= Moderately Resistant, MS= Moderately Susceptible, VS= Very Susceptible, UN=Un Notified

Fig.1 Uredia on the leaf blade

Fig.2 Uredospores

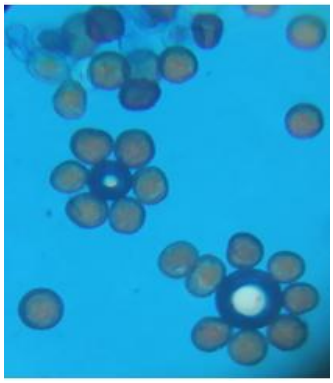

Fig.3 Telia on the lower surface

The germination of uredospores of LR ranges from 2-30°C (best at 20°C), the formation of appressoria best at 15-20°C, penetration at 10-30°C (opt. at 20°C), growth at 2-35°C (opt. 25°C) and sporulation at 10-35°C (best at 25°C) were observed(Singh *et al.*, 2002). The analysis of direct weather data revealed the association of LR severity with a night temperature of <14.25C while the estimated dataset showed that its severity is better explained by the dew point temperature of <13.7 and a mean temp. of <19.06C (Victor *et al.*, 2020).

LR developed optimally at temp. between 59 & 71°F and the disease will progress until the temperatures are above 80°F, infection is completed in 6-8 hrs. and uredospores are capable of causing secondary spread of the disease in 7-10 days (Marsalis, and Goldberg, 2017). Leaf wetness and RH are other factors which are responsible for LR development. A nearly optimum temperatures and leaf wetness period of 6 hours results in 60 - 65% of pustule formation within 12 to 24 hrs wetness period (Stuckey and Zadoks 1989). Favourable weather conditions (temperature, RH, rainfall and cyclone) play a crucial role in long distance spread and epiphytotic. In the present study the disease was favoured by moderate temperature and high humidity for a longer period i.e., from the last week of February to third week of March during crop season 2019-20 (Table 1). Satna had the optimum weather conditions where favourable temperature, RH, leaf wetness and cyclone (western disturbance) were prevailed. Weather data of fourth weeks of February 2020 (table 1) i.e., mean mim., max. and average temp. (15.43, -28.28 and 21.85°C respectively), mean mim., max. and average RH (46.71, 89.57 and 68.14% respectively) and winter rainfall (21mm.) favoured the disease infection through germination of uredospores, formation of appressoria and penetration of germ tube, as low temperature and humid conditions are required for successful infection establishment (Stubbs *et al.*, 1986). Further, the weather data of three weeks of March 2020 i.e., mean mim., max. and average temp. (16.52, 29.85 and 23.18°C respectively), mean mim., max. and average RH (39.09, 84.66 and 61.87% respectively) and winter rainfall (20mm.) favoured the disease development through growth and sporulation of fungus. The same impact of epidemiological factors on the development of *Puccinia recondita* Rox. Ex Desm. on Wheat was observed in Pakistan (Riaz et. al. 2013). Most of wheat varieties grown during the experiment were become susceptible for LR disease due to favourable weather for LR fungus. For LR development, temperature ranging between 10 - 30°C (Singh *et al.*,

2002), 7-10 days period at optimum and constant temperature from spore germination to sporulation and spores can be reached at maximum in about 4 days at 20°C (Marsalis, and Goldberg, 2017; Stubbs et. al. 1986). Rainfall in February played a significant role in spreading the inoculum from south through western disturbance. Dissemination of LR from southern foci to central India is reported to be associated with cyclonic rains (Nagarajan and Singh 1973, 1974). It has also been observed that the amount of precipitation and number of rainy days are more in epidemic than non-epidemic years (Nagarajan and Joshi 1978a) and the present experiment also justified these conditions in LR development. Temperature rise above normal and increased humidity will predispose the crop to severe LR infection and encourage pathogen.

The LR disease of wheat is devastating as its uredospores spread by air currents over long distances and other weather factors like moderate temp., leaf wetness, RH and winter rainfall are also important significantly. It has resulted in failure of crop resistance and a considerable loss to wheat production. In present experiment most of wheat varieties were found very susceptible, susceptible and moderately susceptible. It is concluded that the deterioration in resistance against LR is due to favourable weather conditions, evolution of new races of LR fungus or continuous growing of the high yielding varieties for a long time or due to combined effect of these all factors. Since, high yielding varieties have remained popular among the farmers as these are cost effective and environmentally safe but these varieties are more prone to diseases. Because, weather cannot be controlled by the farmers and they do not follow any management method as protective or curative in their standing wheat crop at the time of disease outbreak therefore, farmers can grow these resistant varieties for riskless and constant production even in the favourable weather conditions for the LR disease during the cropping season and the immune & very resistant lines can also be used in breeding programs.

Acknowledgments

I acknowledge the AKS University, Satna, M.P., India for undertaking the different activities of research presented in this manuscript.

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How to cite this article:

Doomar Singh. 2021. Role of Weather Factors and Wheat Varieties on the Occurrence of Leaf Rust of Wheat in Satna, M.P. India. *Int.J.Curr.Microbiol.App.Sci.* 10(05): 463-471.
doi: https://doi.org/10.20546/ijcmas.2021.1005.054