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Research Article

Determination of Effective Meteorological Parameters for Wheat Diseases in the Central Part of Punjab

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ABSTRACT

The effect of meteorological parameters on incidence and severity of diseases in wheat crop was studied using weather data of the years *rabi* 2012-13 (the highest severity year of yellow rust) and *rabi* 2014-15 (the highest incidence year of Karnal bunt), and was compared with that of the year *rabi* 2020-21 (recent *rabi* season). The area under the disease progress curve (AUDPC) was calculated from disease severity data for the highest (2012-13) and most recent (2020-21) rust severity years. The area under the disease progress curve was higher in Rabi 2012-13 (661.5) than in 2020-21 (399.7). The meteorological parameters affecting wheat yellow rust severity were identified by developing a correlation matrix for both years. In both years under study, maximum and minimum temperatures showed a significant positive correlation with rust severity at the 99% significance level {t(0.01,11) = 2.72 (two-tailed)}. Morning and evening relative humidity were negatively correlated with rust severity in both years under study. Total rainfall was positively correlated with the year of the highest disease severity (2012-13) and negatively correlated with the year of the most recent rust severity (2020-21). This may be due to variability in the amount and timing of rainfall between the two years. The sunshine hours were positively correlated with rust severity during both years under study. On the other hand, the highest incidence of Karnal bunt disease was observed in the year 2014-15, and it was compared with the *rabi* 2020-21. The meteorological parameters affecting Karnal bunt incidence are identified as temperature (maximum and minimum) and rainfall.

Key words: Wheat, Yellow rust, Karnal bunt, Meteorological parameters, Correlation coefficients

Introduction

Climate variability is characterized by increasingly unpredictable and extreme weather patterns, influenced by both natural processes and human-induced climate change. Phenomena like El Niño and La Niña continue to play significant roles in altering global weather patterns, causing extreme events such as severe droughts, floods, and hurricanes etc. In recent years, the frequency and severity of such events have increased, driven largely by the continued rise in global temperatures associated with greenhouse gas emissions. The IPCC report (Lynn and Peeva, 2021) predicts that climate change will intensify across all regions in the coming decades. With global warming reaching 1.5°C, more frequent heat waves, longer warm seasons, and shorter cold seasons can be expected. In India, the

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period from 2020 to 2023 has witnessed a series of climate-related events that have severely impacted agricultural productivity. The Punjab region is also experiencing significant annual fluctuations in temperature and precipitation, resulting in considerable variability in agricultural productivity. A decrease in rainfall and an increase in temperature from northeast to southwest Punjab were observed during both the *kharif* and *rabi* seasons (Kingra *et al.,* 2017). Over the past decade, the abnormal weather conditions have already begun to impact wheat crop productivity. The study by Kingra (2016) reported that lower minimum temperatures, lower relative humidity, lower rainfall, and fewer rainy days during wheat's reproductive growth period in February and March were favourable for higher grain yields. A notable increase in mean temperature has been observed during the wheat growing season. Increased temperatures during March further compound the issue, exacerbating the severity of terminal heat stress. Reports indicate a 40–45% decline in wheat productivity due to rising temperatures (Singh *et al.,* 2013).

Along with increasing abiotic stress, the dynamics of crop diseases have also changed. The most serious constraints to protect yield that have emerged in the last few years is susceptibility of wheat cultivars to diseases like yellow rust and Karnal bunt under changing climatic conditions (Anand *et al.,* 2023). The yellow/stripe rust that is caused by *Puccinia striiformis* f. sp. *tritici* poses a threat in 10 m ha of northern India (Bhardwaj *et al.,* 2019). The stripe rust has been reported to cause the loss of 236 corers in Punjab. Over the last 10 years, stripe rust has made its first appearance in wheat fields in the sub-mountainous districts of Punjab. The highest disease severity has been recorded in the districts of Gurdaspur, Hoshiarpur, Rupnagar, and SBS Nagar (Devi *et al*., 2017). Pannu *et al.* (2010) reported that stripe rust appeared in severe form in plain areas of Jammu and Kashmir, the foothills of Punjab and Himachal Pradesh, parts of Haryana, and the Tarai region of the Uttarakhand hills during 2008-09, 2009-10, and 2010-11. Among post-harvest diseases, Karnal bunt (caused by the fungus Neovossia indica) is the major disease, showing an increasing trend in severity and prevalence from 2012-13 to 2014-15. In 2012-13, Karnal bunt severity was 0.198, increasing to 0.241 in 2013-14. There is a 10 times increase in disease severity in 2014-15. The reason for this could be the prevalence of favourable weather conditions, i.e., high rainfall, more rainy days, and low temperatures below 25°C during February-March, during the heading stages of the crop. During the cropping season 2015-16, there was a sharp decrease in Karnal bunt disease as compared to 2014-15 due to unfavourable environmental conditions at the anthesis stage of the crop (Kaur *et al.,* 2018). Employing epidemiology as a key tool becomes crucial for plant protection, evaluating crops in fields and model farms and inspecting storage facilities to ascertain the status of grain lots for national consumption (Anand *et al.* 2025). Thus, the study of weather parameters and their effects on pathogen development can help enable the timely detection and management of plant diseases. This analysis was conducted to determine the meteorological parameters that effectively influence the incidence and severity of wheat diseases in the Ludhiana district of Punjab.

Material and Methods

To study the effect of meteorological parameters on the incidence and severity of diseases in wheat crop, the weather data of the years 2012-13 (the highest severity year of yellow rust) and 2014-15 (the highest incidence year of Karnal bunt) were compared with the recent Rabi season 2020-21. The meteorological data were collected from the Agrometeorological Observatory at Punjab Agricultural University, Ludhiana, which is situated at 30°54′N latitude and 75°48′E longitude, at an altitude of 247 m above mean sea level. Yellow rust severity (2012-13 and 2020-21) was recorded at weekly intervals after the disease was first observed. Severity index was calculated from the proportion of plant tissue infected by the disease using the following formulae:

$$\text{Severity index} = \frac{\text{Area of plant tissue infected}}{\text{Total area}} \times 100$$

For estimating the per cent severity on leaves, different scales as Modified Mannar's scale for yellow rust of wheat, were used (Peterson *et al.*, 1948)

Rating scale for yellow/stripe rust of wheat

Code	Scale for the severity of infection
5	Up to 5 per cent leaf area infected
10	Up to 10 per cent leaf area infected
20	Up to 20 per cent leaf area infected
50	Up to 50 per cent leaf area infected
75	Up to 75 per cent leaf area infected
100	Up to 100 per cent leaf area infected

Area under disease progress curve (AUDPC)

The rust data was recorded weekly from the appearance of symptoms on the leaves of the crop under field conditions. Area under disease progress curve was calculated from total disease severity observations recorded from the field by using the formula given by Wilcoxson *et al.* (1975), who quantified the AUDPC as following:

$$\mathrm{AUDPC} = \sum_{i=1}^{n=1} \left(\frac{Xi+Xi+1}{2}\right) \times (ti + 1 - ti)$$

Where,

X*i* = Disease severity on date *i*

t*i*= time in days between *i* and date *i* + 1

n = number of observations

A correlation matrix was developed to evaluate the relation between rust severity and various meteorological parameters, and its significance was tested using Student's t-test.

Disease Incidence

For estimating the incidence of Karnal bunt at the harvest stage, and to calculate the per cent disease incidence following formulae were used:

Disease incidence (%) =

$$\frac{\text{No. of diseased grains}}{\text{Total no. of grains examined}} \times 100$$

Samples for Karnal bunt infection were collected from the grain market in Ludhiana during both years of the study, and the average incidence was calculated. To determine the relationship between wheat disease and different meteorological parameters, data were analysed by plotting graphs of meteorological parameters during both years, along with normal meteorological data.

Results and Discussion

Variability in wheat diseases during different seasons

The effect of meteorological parameters on incidence and severity of diseases in wheat crop was studied using weather data of years 2012-13 (the highest severity year of yellow rust) and 2014-15 (the highest incidence year of Karnal bunt), and compared with that of year 2020-21 (the recent Rabi season). The severity index was calculated from the proportion of plant tissue infected by the disease. The yellow rust severity was observed to be higher in *Rabi* 2012-13 as compared to *Rabi* 2020-21, as presented in Fig. 1. Rust severity was recorded from the onset of disease symptoms to the maximum leaf coverage. AUDPC was calculated from disease severity data of the highest (2012-13) and recent (2020-21) rust severity years. The area under the

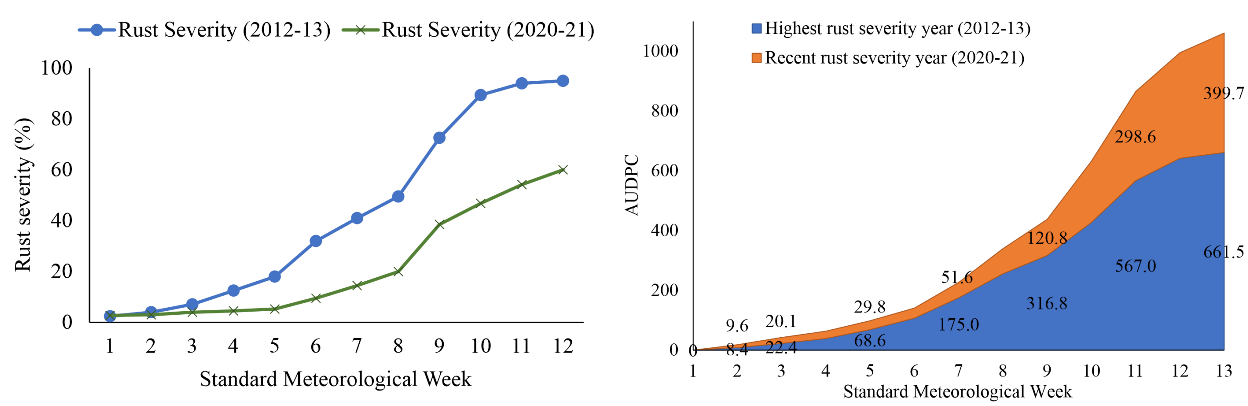

Fig. 1. Yellow rust severity and area under disease progress curve (AUDPC) in *rabi* 2012-13 and 2020-21

Table 1. Per cent Karnal bunt infection in the samples

Year	% Infected Sample	% Average KB Infection
2014-15	98	2.66
2020-21	30	0.30

disease progress curve was higher in 2012-13 (661.5) than in 2020-21 (399.7).

To evaluate Karnal bunt in the Ludhiana district, grain samples were collected from the grain market in Ludhiana. It was observed that during 2014-15, 98 per cent of the samples were infected with Karnal bunt, whereas in 2020-21, only 30 per cent of the samples were infected (Table 1). The per cent average Karnal bunt infection was 2.66 % in 2014-15 and 0.30 % in 2020-21.

Meteorological parameters and wheat diseases

The descriptive statistics of the studied factors, viz., weather and disease data for yellow rust of wheat and Karnal bunt of wheat, are presented in Tables 2 and 3. In these tables, ranges of different meteorological parameters, along with their means and standard deviations, are presented for higher-disease years and recent years. Temperature also influences the germination, infection, and survival of spores. Maximum temperature during the recent

Table 2. Descriptive statistics of studied parameters for yellow rust of wheat

Parameter	Minimum	Maximum	Mean	Standard Deviation
Tmax(°C)-I	10.5	28.8	21.8	5.26
Tmax(°C)-II	14.1	32.2	23.4	5.91
Tmin(°C)-I	4.2	14.6	9.2	3.56
Tmin(°C)-II	6.3	15.7	10.7	3.74
RHm(%)-I	90	99	96	2.72
RHm(%)-II	73	96	89	7.56
RHe(%)-I	48	75	59	9.67
RHe(%)-II	25	75	51	16.6
RF(mm)-I	0	36	13.4	15.2
RF(mm)-II	0	17	2.53	5.41
SSH(hr/day)-I	0.2	10.0	7.00	2.92
SSH(hr/day)-II	0.5	9.8	5.73	2.85

#I-Data for year 2012-13 and II-Data for year 2020-21

Table 3. Descriptive statistics of studied parameters for Karnal bunt of wheat

Parameter	Minimum	Maximum	Mean	Standard Deviation
Tmax(°C)-I	18.6	30.2	23.6	3.81
Tmax(°C)-II	20.6	32.3	26.5	4.09
Tmin(°C)-I	6.3	15.7	10.7	3.74
Tmin(°C)-II	6.2	15.6	12.2	3.54
RHm(%)-I	87	96	92	2.52
RHm(%)-II	73	96	87	8.40
RHe(%)-I	52	77	62	7.52
RHe(%)-I	25	69	44	13.1
RF(mm)-I	0	36.2	13.8	11.7
RF(mm)-II	0	17	2.4	5.71
SSH(hr/day)-I	3.6	9.7	6.6	1.71
SSH(hr/day)-I	4.2	9.8	7.1	1.85

#I-Data for year 2014-15 and II-Data for year 2020-21 rust severity year (2020-21) was mostly higher than the highest rust severity year (2012-13) and normal maximum temperature during rust initiation, development and spread period i.e. from 1st SMW to 13th SMW (Fig.2). The maximum temperature during 2012-13 was in range of 10.5-28.8°C whereas during 2020-21, it was in range of 14.1-32.2°C. It indicates that the higher temperatures in the upper range are not favourable for disease spread. In r*abi* 2020-21, during January, the maximum temperature was lower than in 2012-13 and normal. Similarly, Singh *et al.* (2007) also observed that continuous low temperatures in January did not favour the severity of yellow rust. During the highest rust severity year (2012-13), the minimum temperature was above normal from 5th SMW to 12th SMW and lower than that in the recent rust severity year (2020-21) from 1st SMW to 13th SMW. The minimum temperature during 2012 13 was in the range of 4.2-14.6 °C, as compared to 2020-21, where it was 6.3- 15.7 °C. During 7th SMW to 13th SMW (disease spread period), the minimum temperature was abnormally high during the recent year (2020-21) as compared to the highest rust severity year (2012-13) and the normal minimum temperature. Sandhu and Dhaliwal (2017) reported that a higher-than-normal minimum temperature range (especially during the 7th and 8th SMW) favoured the development of yellow rust. Higher morning relative humidity during the highest rust severity year (2012-13) was observed than that of the recent rust severity year (2020-21) from 4th SMW to 13th SMW. It was mostly higher than normal during the highest rust severity year (2012-13), from 1st SMW to 13th SMW, except at 2nd SMW. During 2012-13, morning relative humidity was in the range of 90-99 per cent, compared with 73-96 per cent in 2020-21. So it indicates that higher morning relative humidity favours disease development. From 8th to 13th SMW, the evening relative humidity during the highest rust severity year (2012-13) was higher than normal and in the range of 48-75 per cent and that of the recent year (2020-21). Evening relative humidity during the highest-rust-severity year (2012-13) was lower (from the 1st SMW to the 4th SMW) than that in the recent year (2020-21). The evening relative humidity during the recent year (2020-21) was lower (from the 4th to the 6th SMW and from the 8th to the 13th SMW) than in the highest-rust-severity year. Sandhu *et al.* (2017b) reported that evening relative humidity was negatively correlated with disease severity. Low sunshine hours during the recent rust severity year (2020-21) were observed compared to those of the highest rust severity year (2012-13), except in the 5th, 8th and 13th SMW. It was also lower than normal except during the 9th and 13th SMW. Sunshine hours were mainly higher than the recent rust severity year (2020-21) from 10th to 12th SMW. Sandhu and Dhaliwal (2017) also reported a positive

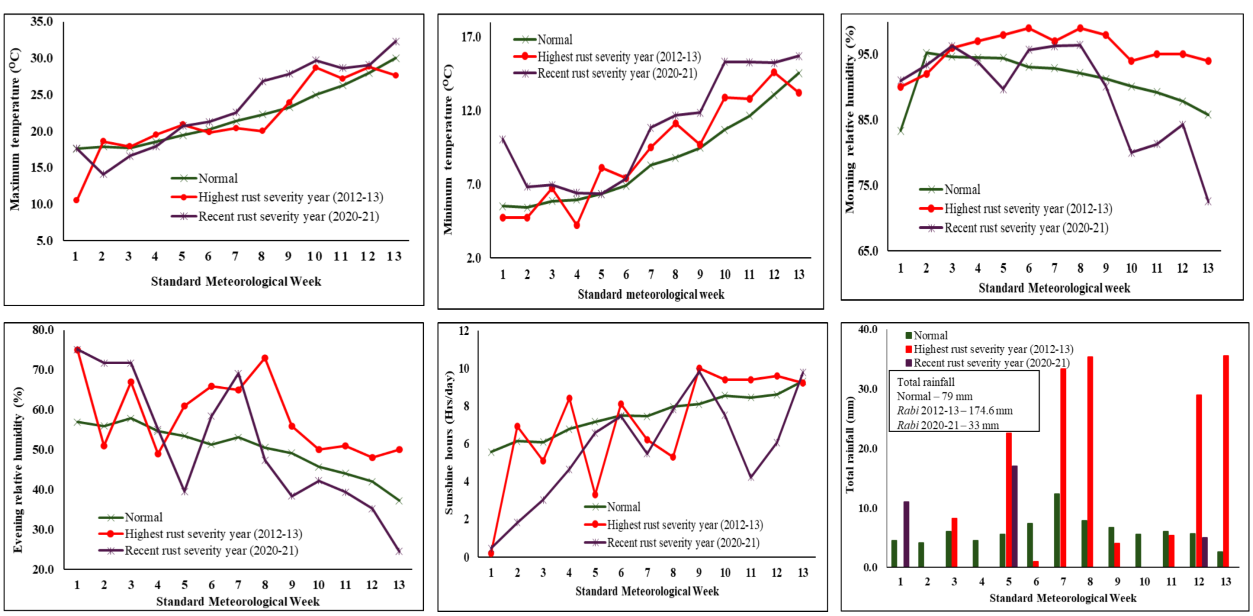

Fig. 2. Comparison of weekly meteorological parameters during the highest and recent rust severity years

correlation of sunshine hours with rust severity. Total rainfall was mostly higher during the highest rust severity year (2012-13) than the normal and recent rust severity year (2020-21). During the highest rust severity year (2012-13), total rainfall received was higher during 7th (33.4 mm), 8th (35.4 mm) and 13th SMW (35.6 mm). High rainfall was recorded at 1st SMW (11 mm) and 5th SMW (17 mm) in the recent year (2020-21). During *rabi* 2012-13, a very high amount of rainfall (174.6 mm) was received during the disease development and spread period as compared to normal rainfall (79.0 mm). Whereas during the recent rabi year (2020-21), Ludhiana received very little rainfall (33.0 mm) during the period of disease development and spread. Anand *et al.* (2023a) demonstrated that optimal urediniospore germination of *Puccinia striiformis* occurred at 15°C, whereas *Puccinia triticina* peaked at 20°C, with a neutral pH (7) and intense light (1250 lux) further promoting germination.

Various meteorological parameters were analysed to determine their role in the incidence of Karnal bunt during the period of highest and most recent incidence. Maximum temperature during the recent year (2020-21) was mostly higher (20.6-32.3^{o}C °C) than normal, and the highest Karnal bunt incidence year (18.6-30.2) from 5th SMW to 13th SMW (Fig. 3). Maximum temperature during the year of highest Karnal bunt incidence (2014-15) was mostly below normal from 9th to 11th SMW and 12th to 13th SMW. It indicates that the maximum temperature below normal during the 9th SMW to the 11th SMW is favourable for disease spread. The minimum temperature was mostly above normal during both the highest Karnal bunt incidence year (2014-15) and the recent rabi season (2020-21), from 5th SMW to 13th SMW. During 9th SMW to 12th SMW, the minimum temperature was higher during the recent Karnal bunt incidence (2020-21) than during the highest Karnal bunt incidence year (2014-15). During recent years, the minimum temperature during the 9th SMW to the 12th SMW triggered disease development. Higher morning relative humidity (87-96%) during the highest Karnal bunt incidence year (2014-15) was observed than that of recent years (73-96%) from 9th SMW to 13th SMW. Hence, higher morning relative humidity favours disease development. From 8th to 13th SMW, the evening relative humidity during the highest Karnal bunt incidence year (2014-15) was higher than normal and that of the recent Karnal bunt incidence year (2020-21). Evening relative humidity during the highest Karnal bunt incidence year (2014-15) was higher (from 5th SMW to 13th SMW) than that of the recent Karnal bunt incidence year (2020-21). The evening relative humidity during the recent Karnal

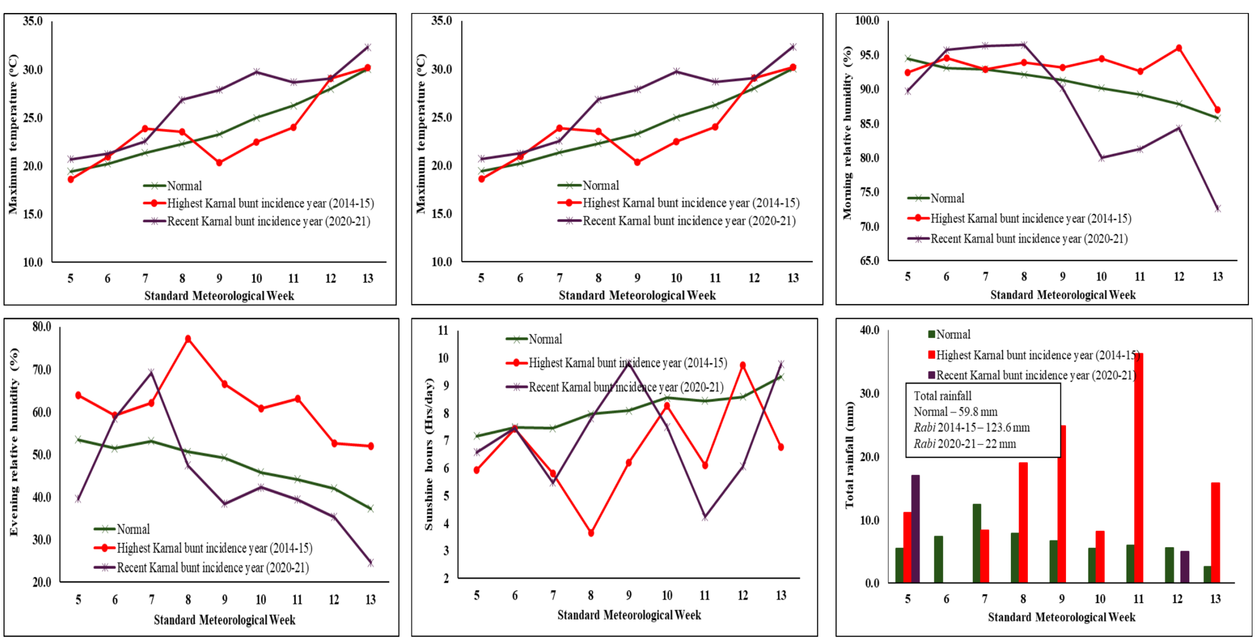

Fig. 3. Comparison of weekly meteorological parameters during the highest and recent Karnal bunt incidence years

bunt incidence year (2020-21) was lower (25-69%) than the highest Karnal bunt incidence year (52-77%). Low sunshine hours during the recent Karnal bunt incidence year (2020-21) were observed compared to those of normal, except in the 9th and 13th SMW. It was also lower in the case of the highest Karnal bunt incidence year (2012-13) than normal from 1st SMW to 13th SMW, except 12th SMW. Sunshine hours were mainly higher than the recent Karnal bunt incidence year (2020-21) from 10th to 12th SMW. Total rainfall was higher during the year of the highest Karnal bunt incidence (0-36.2 mm) than in normal and recent years (0-17 mm). During the highest Karnal bunt incidence year (2014-15), total rainfall received was higher than normal during the 5th (11.2 mm), 8th (19 mm), 9th (24.8 mm), 10th (8.2 mm), 11th (36.2 mm) and 13th (15.8 mm) standard meteorological weeks. Thus, high rainfall is conducive to disease development. Tyagi *et al.* (2013) also reported that the most likely reason for the decline in wheat production during 2012-13 was the humid phase with moderately high minimum temperatures, which led to the occurrence of brown and yellow rust, black point, and Karnal bunt fungal diseases during the grain-filling stage.

Correlation coefficient between rust severity and meteorological parameters

During both the years under study, maximum temperature {r = 0.878 (2012-13), r = 0.857 (2020-21)} and minimum temperature {r = 0.934 (2012-13), r = 0.882 (2020-21)} showed a significant positive correlation with rust severity at 99% significance level {$t_{(0.01,11)} = 2.72$ (two tail)} as shown in Table 4. Kashyap *et al.* (2018) also reported a positive correlation between maximum temperature and rust severity, and Sandhu and Dhaliwal (2017) reported a positive correlation between minimum temperature and rust severity. Morning relative humidity {r = -0.042 (2012-13), r = 0.874 (2020-21)} and evening relative humidity {r=-0.551(2012-13), r = -0.794(2020-21)} were found to be significantly negatively correlated with rust severity during both the years under study. Sandhu *et al.* (2017a) also reported that evening relative humidity was negatively correlated with rust severity. Total rainfall was significantly positively correlated (r = 0.423) during the highest disease severity year (2012-13), whereas it showed a negative correlation (r = -0.204) during the recent rust severity year (2020-

Table 4. Correlation coefficient between rust severity and meteorological parameters in 2012-13 and 2020-21

	DS	Tmax	Tmin	RHm	RHe	Rainfall	SSh
				2012-13			
DS	1.000						
Tmax	0.878*	1.000					
Tmin	0.934*	0.865*	1.000				
RHm	-0.042*	0.176*	0.129*	1.000			
RHe	-0.551*	-0.742*	-0.366*	0.147*	1.000		
RF	0.423*	0.289*	0.542*	0.291*	0.106*	1.000	
SSh	0.661*	0.832*	0.555*	0.256*	-0.778*	-0.014*	1.000
				2020-21			
DS	1.000						
Tmax	0.857*	1.000					
Tmin	0.882*	0.902*	1.000				
RHm	-0.874*	-0.729*	-0.774*	1.000			
RHe	-0.794*	-0.855*	-0.643*	0.743*	1.000		
RF	-0.204*	-0.219*	-0.249*	0.001*	-0.019*	1.000	
SSh	0.465*	0.749*	0.418*	-0.366*	-0.772*	-0.228*	1.000

*Significant at the 0.01 level

Where, Tmax: Maximum temperature (°C), Tmin: Minimum temperature (°C), RHm: Morning relative humidity (%), RHe: Evening relative humidity (%), RF: Rainfall (mm), SSh: Sunshine hours (hrs/day)

21). The sunshine hours were positively correlated with rust severity in both years under study: {r = 0.661 (2012-13), r = 0.465 (2020-21)}. Sandhu *et al.* (2017b) also reported a significant positive correlation of sunshine hours with rust severity.

Conclusion

Wheat disease dynamics are governed by inter-annual variability in key meteorological drivers acting during critical phenological stages. While warming trends may suppress disease under extreme conditions, episodic humid and wet phases can still trigger severe outbreaks. Disease expression was favoured under cool, humid weather, whereas warmer, drier conditions constrained epidemic development. The positive correlation between sunshine hours and rust severity suggests that intermittent periods of bright light following humid and wet conditions may accelerate disease progression by supporting spore viability and host susceptibility. Karnal bunt incidence was closely associated with cooler maximum temperatures, elevated minimum temperatures, high humidity, and frequent rainfall during the grain-filling stage, whereas warmer and drier conditions markedly reduced disease occurrence.

References

Anand, S., Sandhu, S.K. and Tak, P.S. 2025. Influence of prevailing weather variables on Karnal bunt dynamics in wheat. *Agricultural Research Journal,* **62**: 345-352.

Anand, S., Sandhu, S.K., Biswas, B. and Bala, R. 2023. Comparative analysis of different Karnal bunt disease prediction models developed by machine learning techniques for Punjab conditions. *International Journal of Biometeorology*, **68**: 1799-1810.

Anand, S., Sandhu, S.K. and Tak, P.S. 2023a. Effect of abiotic factors causing yellow and brown rust in wheat. *Journal of Agrometeorology*, **25**: 462-65.

Bhardwaj, S.C., Singh, G.P., Gangwar, O.P., Prasad, P. and Kumar, S. 2019. Status of wheat rust research and progress in rust management- Indian context. *Agronomy*, **9**: 892-906.

Devi, H.M., Mahapatra, S., Dutta, S. and Das, S. 2017. Influence of phenological growth stages and meteorological parameters on leaf blight infestation of wheat in Gangetic plains of West Bengal. *Journal of Wheat Research,* **9**: 101-07.

Kashyap, S., Pannu, P.P.S., Kaur, G., Sandhu, S.K. and Singh, P. 2018. Effect of weather parameters on occurrence and development of stripe rust of wheat in central Punjab. *Plant Disease Research* **33**: 76-81.

Kaur, J., Bala, R., Kaur, H., Pannu, P.P.S., Kumar, A. and Bhardwaj, S.C. 2018. Current status of wheat disease in Punjab. *Agric. Res. J.,* **55**: 113-16.

Kingra, P.K. 2016. Climate variability impacts on wheat productivity in central Punjab. *Journal of Agrometeorology*, **18**: 97-99. https://doi.org/10.54386/jam.v19i3.664

Kingra, P.K., Setia, R., Singh, S., Kaur, J., Kaur, S., Singh, S.P., Kukal and Pateriya, B. 2017. Climatic variability and its characterisation over Punjab India. *Journal of Agrometeorology*, **19**: 246-250. https://doi.org/10.54386/jam.v19i3.664

Lynn, J. and Peeva, N. 2021. Communications in the IPCC's Sixth Assessment Report cycle. *Climate Change*, **169**: 18.

Sandhu, S.K. and Dhaliwal, L.K. 2017. Assessment of weather-disease-yield interactions in wheat under Central Punjab. *Journal of Agricultural Physics*, **17**: 216-23.

Sandhu, S.K., Dhaliwal, L.K. and Pannu, P.P.S. 2017a. Effect of weather parameters on incidence and severity of stripe rust in wheat under natural and artificial conditions. *Journal of Agrometeorology,* **19**: 272-7.

Sandhu, S.K., Dhaliwal, L.K. and Pannu, P.P.S. 2017b. Effect of meteorological and micrometeorological parameters on stripe rust severity of wheat. *International Journal of Current Microbiology and Applied Sciences*, **6**: 4512-20.

Singh, R.P., Vara Prasad, P.V. and Raja Reddy, K. 2013. Impacts of changing climate and climatic variability on seed production and seed industry. *Adv Agron.,* **118**: 49-110.

Tyagi, S.K., Singh, R., Krishnan, P. and Verma, R. 2013. Variations in meteorological conditions resulted decline in wheat yield in North-West Indo-Gangetic plains. *Journal of Agricultural Physics*, **13**:75-81.

Wilcoxson, R.D., Skovmand, B. and Atif, A.H. 1975. Evaluation of wheat cultivars for ability to retard development of stem rust. *Annals of Applied Biology,* **80**: 275-81.

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