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Effect of weather variability on foliar blight severity in wheat (*Triticum aestivum*) across different agroclimatic locations of Punjab

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ABSTRACT

Foliar blight severity in wheat (*Triticum aestivum* L.) is highly dependent on prevailing weather conditions, sowing time and crop microclimate that together influence disease dynamics. In line with this, present study was carried out during winter (*rabi)* seasons of 2021–22 and 2022–23 at Punjab Agricultural University, Ludhiana, Punjab and Regional Research Station, Gurdaspur Punjab to investigate the effect of weather variability on severity of foliar blight with three wheat varieties, viz. PBW 725, HD 2967 and HD 3086 sown on different dates (14th–15th October, 8th–9th November and 3rd–4th December) under two microclimate modification levels i.e. M_1 (recommended irrigation) and M_2 (additional water sprays). The experiment was laid out in split plot design (SPD) with four replications. It was observed that early date of sowing (14–15th October) recorded higher foliar blight severity at Ludhiana (28.52%, 29.35%) and Gurdaspur (21.69%, 30.65%) in variety HD 3086 in M_2 than other treatments, respectively. The highest mean Area Under Disease Progress Curve (AUDPC) (71.4, 79.1), relative AUDPC (11.1, 12.7) and total AUDPC (571.5, 711.7) in Ludhiana, as well as mean AUDPC (56.5, 83.3), relative AUDPC (9.2, 13.4) and total AUDPC (451.6, 750.1) in Gurdaspur were consistently higher in early sowing under M_2 treatment in variety HD 3086 during both years of the study. Correlation and multiple regression analyses were employed to quantify the relationships between key weather parameters and foliar blight severity, identified minimum temperature, morning relative humidity and rainfall as key parameters in development of this disease. Warm and humid weather, especially after continuous rains, favours rapid foliar blight development. The suitability of regression models can be assessed for real time data in Punjab.

Keywords: AUDPC, Correlation coefficients, Foliar blight, Sowing dates, Weather parameters

Climate change and weather anomalies impact disease dynamics in a region (Skendzic *et al.* 2021). Weather plays crucial role in the outbreak of crop diseases, as illustrated by classic disease triangle model. This concept explains that diseases emerge when pathogen encounters a suitable host in favourable environmental conditions (Francl 2001). Among the biotic stresses that threaten wheat (*Triticum aestivum* L.) yield, foliar blights are becoming pandemic and have replaced rusts in important regions of South Asia (Duveiller *et al.* 2005). In 1996, this disease reached epidemic levels in Punjab and nearby areas due to warm and moist conditions in March and caused about 10% yield loss in various Punjab districts (Kaur and Nanda 1999).

Foliar blight (caused by *Alternaria triticina*) in wheat crop produces round to oblong dark brown spots with distinct margins on leaves which expand into an 'eye' shape, brown pupil and a yellow halo if moisture levels are high (Duveiller and Dubin 2002). As the disease advances, lesions merge and cover large areas. Foliar blights occur particularly in regions with high temperatures (coolest month above 17°C) and high humidity. Continuous rain for 5–6 days followed by warmer temperatures (20–30°C) can quickly trigger spot blotch epidemic (Mehta 1998).

Recently, managing foliar blights has gained more attention to boost crop productivity (Duveiller and Dubin 2002). Re-emergence of such diseases poses significant challenge for farmers and researchers as well. One potential solution is developing weather-based prediction models. By studying the complex interactions among plants, pathogens and environment, these models can guide effective management decisions (Anonymous 2019). Punjab experiences considerable fluctuations in weather parameters like temperature, rainfall and humidity. This weather variability directly influences foliar blight development. Therefore, a comprehensive study was designed to investigate the effect of weather parameters on disease development along with microclimate modification by increasing wetness conditions within crops. The study was carried out with objective to understand how adjusting sowing dates can affect timing and severity of foliar blight, as well as how prolonged periods of leaf wetness can intensify disease progression.

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MATERIALS AND METHODS

The field experiments were carried out during winter (*rabi)* seasons of 2021–22 and 2022–23 at Punjab Agricultural University, Ludhiana (30°40'N, 74°44'E; at an elevation of 247 m amsl), Punjab and Regional Research Station, Gurdaspur (32.05°N, 75.42°E; at an elevation of 247 m amsl), Punjab. The experiment was laid out in split plot design (SPD) with three wheat varieties, viz. PBW 725, HD 2967 and HD 3086 sown on different dates [14th–15th October (D_1), 8th–9th November (D_2) and 3rd–4th December (D_3)] under two microclimate modification levels i.e. M_1 (recommended irrigation) and M_2 (Recommended irrigations + 2 additional water sprays with power knapsack sprayer 10 days and 25 days after disease initiation). Water sprays were given using cut nozzle to imitate rainfall effect. M_2 treatment plots were sprayed nine times (at one hour interval spanning one full day) with four replications.

Study area: The present investigation was conducted at two locations of Punjab at Ludhiana and Gurdaspur. Being part of India's trans-Gangetic agroclimatic zone, Ludhiana is in the central plain region of Punjab. In general, climatic conditions here are subtropical and semi-arid. The average maximum and minimum temperatures for the year are 29.8°C and 16.7°C, respectively and average annual rainfall is 760 mm. While, Gurdaspur is situated in the north Punjab under sub mountain undulating region. This study area comes under sub-tropical and sub-humid climate. This region receives more rainfall (about 1100 mm) as compared to central Punjab and relative humidity remains more than 80% during the rainy (*kharif*) season.

Disease data collection: The foliar blight disease severity involves determination of the plant tissue proportion that was infected by disease. Eyal *et al.* (1987) scale for foliar blight was employed to estimate the severity in per cent on the leaves (0, No Blight; 1, Up to 10%; 2, 11–20%; 3, 21–30%; 4, 31–40%; 5, 41–50%; 6, 51–60%; 7, 61–70%; 8, 71–80%; 9, >80% leaf area blighted). Severity graphs were prepared using the mean values of the respective treatments. Disease severity was calculated from collected data by using following formula:

$$\text{Disease severity (\%)} = \frac{\sum \text{Number of infected leaves} \times \text{Scale}}{\text{Total number of leaves} \times \text{Maximum grade}} \times 100$$

Area under disease progress curve (AUDPC): Weekly observations of foliar blight symptoms on crop leaves were made under field conditions. Using the method provided by Wilcoxson *et al.* (1975), the Area under Disease Progress Curve (AUDPC) was calculated with the total observations recorded on disease severity. The AUDPC was quantified as follows:

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

Where Xi, Disease severity on date i; ti, Time in days between i and date i + 1; n, Number of observations.

$$\text{rAUDPC} = \frac{\text{Total AUDPC}}{\text{Total time (days)}} \times 100$$

Where, rAUDPC (%), Relative AUDPC; Total AUDPC, Sum of weekly AUDPC values; Total time, Total days after disease appearance.

Meteorological data collection: The meteorological data for respective districts were collected from Department of Climate Change and Agricultural Meteorology at PAU, Ludhiana and Regional Research Station, Gurdaspur.

Statistical analysis: To begin analysis, descriptive statistics was applied to meteorological data during crop duration and disease period. Subsequently, correlation coefficients were worked out between meteorological parameters and foliar blight severity using R software. Weather based regression models were also developed.

RESULTS AND DISCUSSION

Foliar blight severity under different treatments: Foliar blight severity was more pronounced at Gurdaspur, ranging from 4.23–30.65%, in comparison to Ludhiana, where the severity varied between 5.05–29.35% (Fig. 1, 2 and 3). Higher foliar blight severity was observed during *rabi* 2022–23 with severity ranging from 7.23–30.65%, contrasting with that during *rabi* 2021–22 (4.23–28.52%). Among different varieties, HD 3086 exhibited the highest susceptibility to foliar blight, with severity ranging between 9.23% and 30.65%, followed by PBW 725 (9.63–27.85%), whereas HD 2967 exhibited the lowest severity levels, ranging from 4.23–10.36%. Early sowing on October 14–15 resulted in the highest foliar blight severity, ranging from 5.05–30.65%, which markedly surpassed the severity observed for sowing on November 8–9 (5.17–25.34%) and December 3–4 (4.23–15.21%). Microclimate modification under the M_2 level consistently manifested higher foliar blight severity, ranging from 5.41–30.65% than M_1, where the severity was observed within the range of 4.23–28.36%. Crop growth stage and weather, particularly high temperatures and humidity that prolonged leaf wetness, are crucial for foliar blight development (da Luz and Bergstrome 1986). The severity of foliar blight correlated with high field temperatures and relative humidity that extended leaf wetness beyond 12 h (Sentelhas *et al.* 1993). Even post-monsoon, without rainfall, high soil residual moisture and foggy days in the Indo-Gangetic Plains can keep leaf blades wet until late January, creating perfect conditions for wheat pathogens (White and Rodrguez-Augilar 2001, de Lespiny 2004). In Brazil, foliar blight outbreaks required wheat leaves to stay wet for over 18 h at a mean temperature of 18°C or higher. Moderate to warm temperatures (18–32°C) promoted *B. sorokiniana* growth (Reis 1991).

The r-AUDPC, total AUDPC and mean AUDPC were significantly higher at Gurdaspur, with ranges of 0.9–13.4, 45.9–750.1 and 5.7–83.3, respectively compared to Ludhiana, where values ranged from 1.19–12.7, 58.38–711.7 and 7.30–79.1, respectively (Table 1). During the *rabi* 2022–23, elevated r-AUDPC (2.24–13.4), total AUDPC

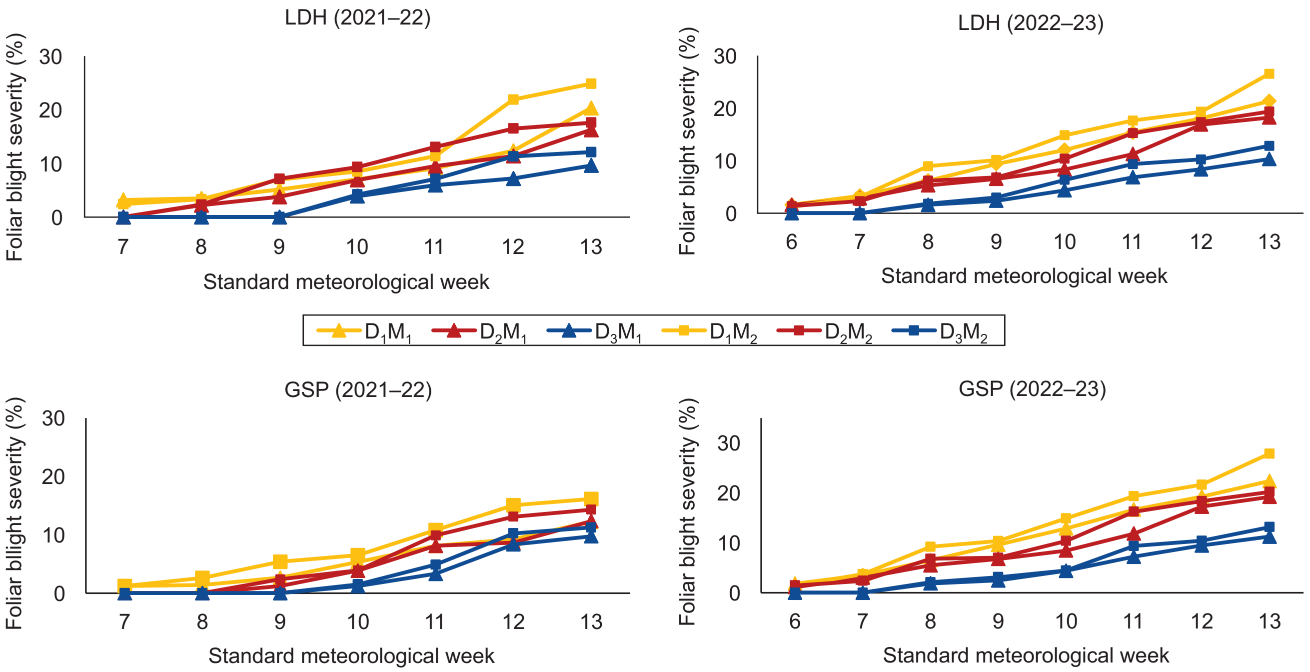


Fig. 1 Foliar blight severity in different dates of sowing and microclimate modification levels in variety PBW 725. LDH, Ludhiana; GSP, Gurdaspur. Treatment details are given under Materials and Methods.

(125.69–750.1), and mean AUDPC (13.97–83.3) were recorded, surpassing the corresponding values observed in the *rabi* 2021–22 (1.19–9.2, 58.38–451.6 and 7.30–56.5, respectively). Among the wheat varieties, HD 3086 exhibited the highest levels of r-AUDPC (3.7–13.4), total AUDPC (179.6–750.1) and mean AUDPC (22.5–83.3), followed by PBW 725 with ranges of 3.1–11.8, 152.8–661.3 and 19.1–73.5, respectively while HD 2967 recorded the lowest values of 1.19–6.1, 58.38–342.5 and 7.30–38.1, respectively. Early sowing dates of October 14–15 resulted in the maximum r-AUDPC (1.99–13.4), total AUDPC (97.69–750.1) and mean AUDPC (12.21–83.3), exceeding the values observed for November 8–9 sowing (1.38–12.4, 67.73–694.9, and 8.47–77.2) and December 3–4 sowing (1.19–5.5, 58.38–306.8, and 7.30–34.1). Under the M_2 microclimate modification, the r-AUDPC (2.76–13.4), total

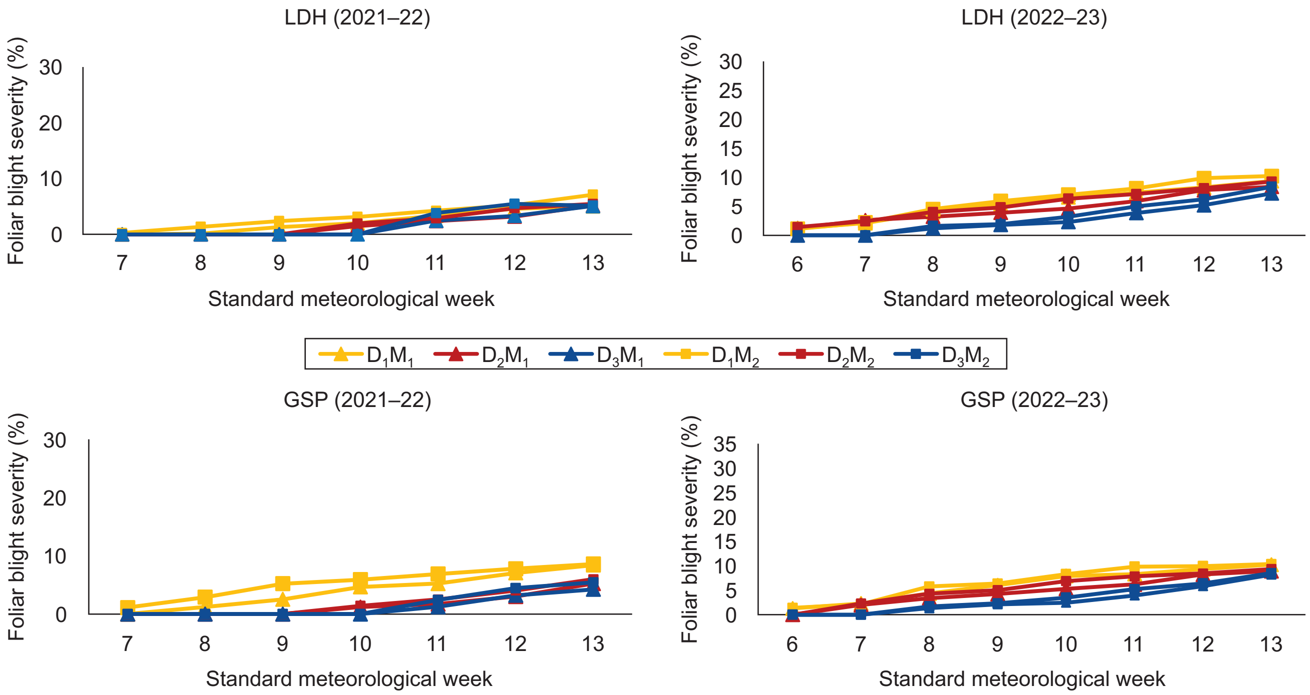


Fig. 2 Foliar blight severity in different dates of sowing and microclimate modification levels in variety HD 2967. LDH, Ludhiana; GSP, Gurdaspur. Treatment details are given under Materials and Methods.

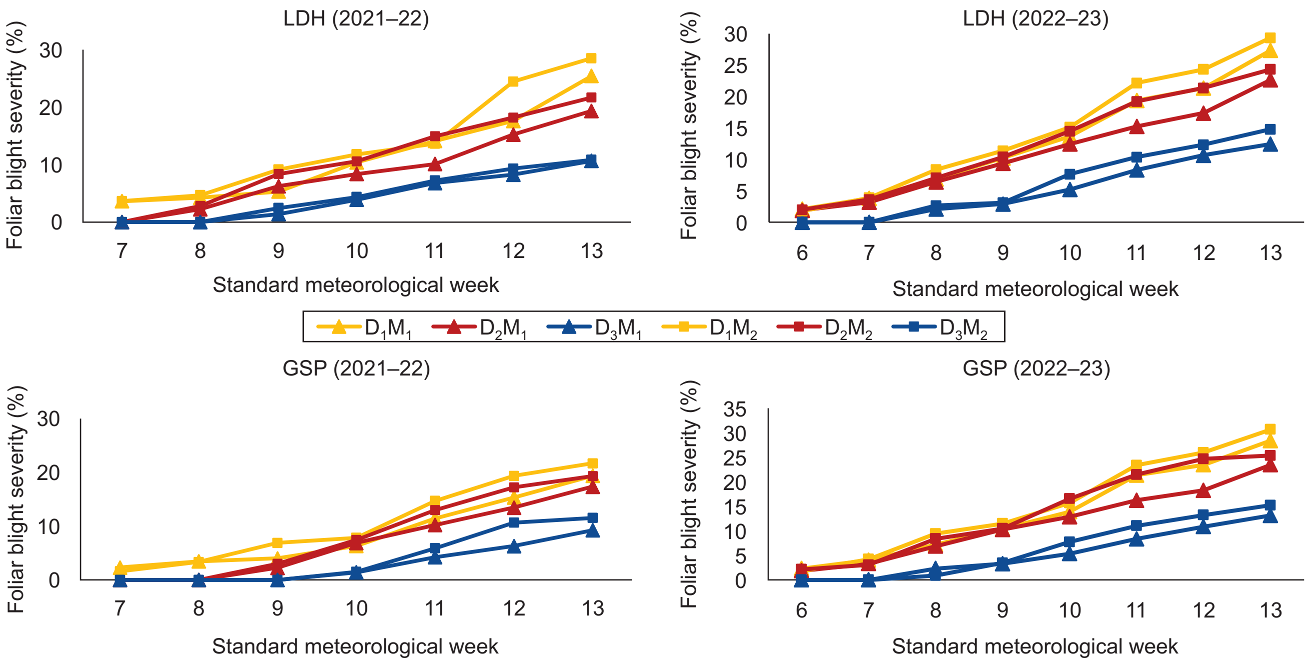


Fig. 3 Foliar blight severity in different dates of sowing and microclimate modification levels in variety HD 3086. LDH, Ludhiana; GSP, Gurdaspur. Treatment details are given under Materials and Methods.

Table 1 Relative, total and mean AUDPC of foliar blight severity in different treatments at Ludhiana and Gurdaspur

Treatments	D$_1$M$_1$		D$_2$M$_1$		D$_3$M$_1$		D$_1$M$_2$		D$_2$M$_2$		D$_3$M$_2$	
	2021–22	2022–23	2021–22	2022–23	2021–22	2022–23	2021–22	2022–23	2021–22	2022–23	2021–22	2022–23
Ludhiana												
PBW 725												
r-AUDPC	7.2	9.6	6.0	7.7	3.1	3.6	9.6	11.1	8.2	8.7	4.1	4.6
Total AUDPC	353.0	536.3	293.0	432.5	152.8	200.6	468.1	619.0	399.4	484.8	200.6	259.8
Mean AUDPC	44.1	59.6	36.6	48.1	19.1	22.3	58.5	68.8	49.9	53.9	25.1	28.9
HD 2967												
r-AUDPC	1.99	4.94	1.38	4.18	1.19	2.24	2.89	5.47	1.75	4.85	1.70	2.76
Total AUDPC	97.69	276.50	67.73	233.87	58.38	125.69	141.58	306.25	85.72	271.53	83.28	154.63
Mean AUDPC	12.21	30.72	8.47	25.99	7.30	13.97	17.70	34.03	10.71	30.17	10.41	17.18
HD 3086												
r-AUDPC	9.7	11.4	7.4	9.7	3.7	4.4	11.7	12.7	9.4	11.3	4.1	5.4
Total AUDPC	476.1	637.4	362.9	541.1	179.6	248.0	571.5	711.7	460.2	631.7	201.1	304.5
Mean AUDPC	59.5	70.8	45.4	60.1	22.5	27.6	71.4	79.1	57.5	70.2	25.1	33.8
Gurdaspur												
PBW 725												
r-AUDPC	4.9	10.2	4.0	7.9	2.5	3.9	7.1	11.8	5.2	9.1	3.2	4.5
Total AUDPC	238.6	569.7	195.8	444.7	124.2	216.9	347.0	661.3	255.2	508.8	155.6	252.1
Mean AUDPC	29.8	63.3	24.5	49.4	15.5	24.1	43.4	73.5	31.9	56.5	19.5	28.0
HD 2967												
r-AUDPC	3.6	5.6	1.2	4.2	0.9	2.5	4.9	6.1	1.6	4.9	1.4	2.9
Total AUDPC	173.8	312.9	59.7	236.9	45.9	138.7	238.4	342.5	76.5	276.6	66.9	163.8
Mean AUDPC	21.7	34.8	7.5	26.3	5.7	15.4	29.8	38.1	9.6	30.7	8.4	18.2
HD 3086												
r-AUDPC	7.5	12.1	5.9	10.2	2.4	4.6	9.2	13.4	7.2	12.4	3.4	5.5
Total AUDPC	367.7	677.0	290.3	568.9	115.9	256.4	451.6	750.1	352.4	694.9	166.7	306.8
Mean AUDPC	46.0	75.2	36.3	63.2	14.5	28.5	56.5	83.3	44.0	77.2	20.8	34.1

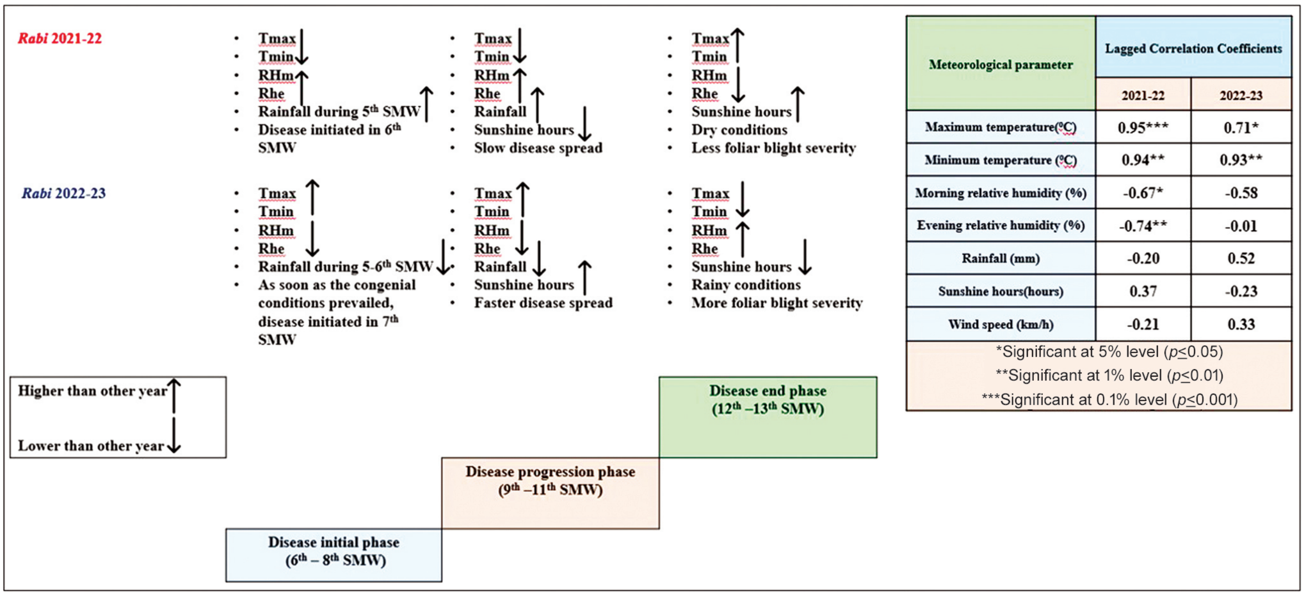
AUDPC, Area under Disease Progress Curve. Treatment details are given under Materials and Methods.

AUDPC (154.63–750.1) and mean AUDPC (17.18–83.3) were consistently higher than those observed under the M_1 level, where values ranged from 1.19–12.1, 58.38–677.0 and 7.30–75.2, respectively.

Descriptive statistics of studied meteorological parameters during crop duration: At Ludhiana, during 2021–22, the range of various meteorological parameters, viz. maximum temperature (13.5–39.9ºC), minimum temperature (5–24.4ºC), morning relative humidity (61–97%), evening relative humidity (13–83%), sunshine hours (0.1–10.7 h/day) and rainfall (0–51.6 mm) were recorded (Supplementary Table 1). The maximum temperature ranged between 13.3°C and 36.1°C, while the minimum temperature ranged from 4.3–22.9°C during 2022–23 at Ludhiana. Morning relative humidity was observed in range of 75–95% and evening relative humidity ranged from 19–72%. Sunshine hours spanned from 1.4 to 11.1 h/day and rainfall varied from 0–33 mm. The cumulative sunshine hours during 2021–22 were 1204.8 h and 1211.5 h in 2022–23. During 2021–22 and 2022–23, the total recorded rainfall at Ludhiana varied, with 195.3 mm in 2021–22 surpassing the 118.1 mm in 2022–23. The distribution of rainfall was uneven across the seasons; in 2021–22, it was concentrated between the 1st and 5th standard meteorological weeks (SMWs), while in 2022–23, it occurred predominantly between the 11th and 14th SMWs. Specifically, Ludhiana received higher amount of rainfall (113.4 mm) in January 2022, contrasting with 18.1 mm in January 2023. Notably, above-normal rainfall of 55.0 mm occurred in March during 2023, whereas a negligible amount of rainfall (0.8 mm) was recorded in 2022. At Gurdaspur, the maximum temperature was in range of 13.6–39.3°C, while the minimum temperature ranged from 3.9–21.7°C during 2021–22. Morning and evening relative humidity ranged from 57–96.7% and 38.4–83.1%, respectively. Sunshine hours spanned from 0–7.9 h/day and rainfall varied from 0–88.1 mm during 2021–22. During 2022–23, the range of various meteorological parameters, viz. maximum temperature (11.1–35.7ºC), minimum temperature (3.6–22.4ºC), morning relative humidity (74.2–97.7%), evening relative humidity (33.7–88.1%), sunshine hours (0.6–8.6 h/day) and rainfall (0–36.4 mm) were recorded. Remarkably, higher evening relative humidity was observed during most of the cropping season in 2021–22 as compared to 2022–23. The cumulative sunshine hours for 2021–22 were 967.8 h, exceeding the 926.2 h recorded in 2022–23 at Gurdaspur. Gurdaspur experienced a higher total rainfall of 313.5 mm in 2021–22 compared to 128.2 mm in 2022–23. Like Ludhiana, the distribution was uneven, with the majority in 2021–22 between 1st to 5th SMWs and in 2022–23 between 11th–14th SMWs. During January 2022, Gurdaspur received 207.2 mm rainfall which was significantly higher than 11.4 mm of January 2023.

Descriptive statistics of studied meteorological parameters during disease period: In 2021–22, Ludhiana recorded a maximum temperature ranging from 22.0–35.6°C with a mean of 28.1°C, while Gurdaspur had a slightly similar range of 22.0–36.1°C, with a mean of 27.9°C (Supplementary Table 2). The minimum temperature was slightly lower in Ludhiana (7.2–18.9°C) compared to Gurdaspur (7.6–17.6°C). In 2022–23, both locations showed a slight decline in maximum and minimum temperatures. Ludhiana's maximum temperature ranged from 23.0–28.5°C, whereas Gurdaspur recorded 22.4–28.2°C. The minimum temperature showed a similar declining trend at both locations. *A. triticina* thrives at 25°C, producing maximum sporulation and growth (Ghosh and Gemawat 1979). Morning relative humidity was higher in 2021–22 at both locations, with Ludhiana ranging from 79.0–94.0% and Gurdaspur from 70.6–87.7%. In 2022–23, morning relative humidity ranging between 87.0–90.0% in Ludhiana and between 81.5–89.6% in Gurdaspur. Evening relative humidity showed notable variation between the two seasons and locations. In 2021–22, Ludhiana recorded lower evening humidity (23.0–58.0%, mean 42.7%) compared to Gurdaspur (43.0–67.3%, mean 58.4%). Foliar blights occur particularly in regions with high temperatures (coolest month above 17°C) and high humidity. However, they're also becoming a growing concern in areas with irrigated, low-rainfall, and temperate growing conditions (Van Ginkel and Rajaram 1993). In warmer wheat-growing regions, climate change has amplified foliar blight development due to rising temperatures (Sharma and Duveiller 2007). However, in 2022–23, evening humidity was in range between 38.0–53.0% at Ludhiana and 48.9–60.4% in Gurdaspur. At both locations, during disease development period, the maximum and minimum temperatures were lower while morning and evening relative humidity were higher during 2021–22 than 2022–23. In 2021–22, the maximum amount of rainfall occurred between the 1st and 5th SMW [149.3 mm (Ludhiana) and 235 mm (Gurdaspur)] while in 2022–23, it was concentrated between the 11th and 14th SMW [77.2 mm (Ludhiana) and 78 mm (Gurdaspur)]. Sunshine hours were notably higher in 2021–22, with total of 61.4 h in Ludhiana and 63.2 h in Gurdaspur during disease period. However, in 2022–23, sunshine hours decreased significantly, with 51.6 h in Ludhiana and 39.2 h in Gurdaspur indicating more cloud cover and higher humidity. Continuous rain for 5–6 days followed by warmer temperatures (20–30°C) can quickly trigger a spot blotch epidemic (Mehta 1998). Spot blotch epidemics are likely in areas with average temperatures above 17°C during the coolest months and high relative humidity, particularly in South Asia's rice–wheat systems (Aggarwal *et al.* 2000). Spot blotch develops when leaves stay wet for over 18 h at a mean temperature above 18°C (Couture and Sutton 1978). In South Asia, *C. sativus* infections are more rapid and severe at 28°C (Nema and Joshi 1973). Higher temperatures favour *C. sativus* in traditional wheat areas like Canada (Gilbert *et al.* 1998).

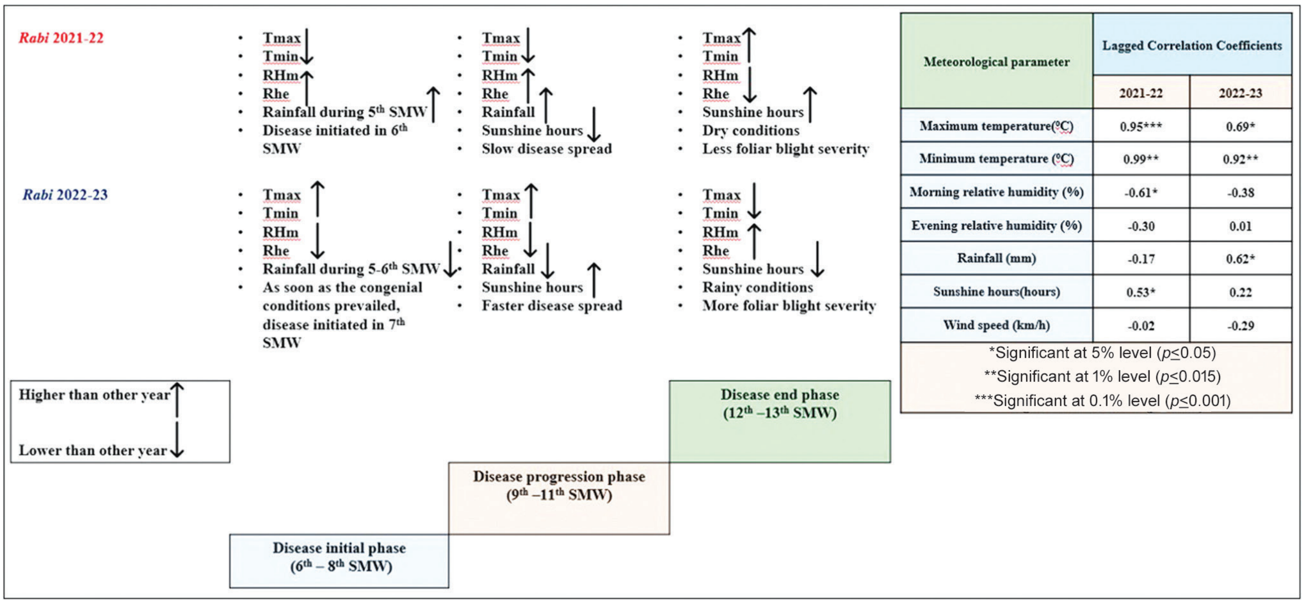
Effect of weather variability on foliar blight severity: The initiation, progression and termination of foliar blight disease in Ludhiana and Gurdaspur were significantly affected by meteorological conditions during *rabi* 2021–22 and 2022–23. The comparison between the two years highlighted how early-season rainfall and humidity levels effected disease initiation, while temperature variations and sunshine duration controlled disease progression. In 2021–22, foliar blight initiated in the 6th SMW, following higher rainfall in the 5th SMW than 2022–23 that provided initial moisture for disease initiation (Fig. 4 and 5). Hence, foliar blight initiation was delayed until the 7th SMW, as conducive conditions emerged later in next week during 2022–23. During both the years, disease symptoms appeared during ear formation stage and anthesis stage. The disease progression phase (9th–11th SMW) was characterised by lower maximum and minimum temperatures along with higher relative humidities (morning and evening) coupled with high rainfall as compared to 2022–23 resulting in slower disease spread during 2021–22 than 2022–23. By the disease end phase (12th–13th SMW), higher maximum and minimum temperatures, lower humidities (morning and evening), dry conditions and increased sunshine hours suppressed disease severity during *rabi* 2021–22 than 2022–23 in which disease end phase was marked by continued rainy conditions, lower maximum and minimum temperatures, higher humidities (morning and evening) and lower sunshine hours, which resulted in higher foliar blight severity than in the previous year. The lagged correlations between foliar blight severity and meteorological conditions before one week have been computed. Lagged correlation analysis revealed that T_{max} and T_{min} maintained strong positive associations with foliar blight severity indicating that antecedent warm conditions predisposed the crop to higher disease development while RHm and RHe showed predominantly negative relationships. Rainfall, sunshine



Meteorological parameter	Lagged Correlation Coefficients	
	2021-22	2022-23
Maximum temperature(°C)	0.95***	0.71*
Minimum temperature (°C)	0.94**	0.93**
Morning relative humidity (%)	-0.67*	-0.58
Evening relative humidity (%)	-0.74**	-0.01
Rainfall (mm)	-0.20	0.52
Sunshine hours(hours)	0.37	-0.23
Wind speed (km/h)	-0.21	0.33

*Significant at 5% level ($p \leq 0.05$)
**Significant at 1% level ($p \leq 0.01$)
***Significant at 0.1% level ($p \leq 0.001$)

Fig. 4 Weather-foliar blight window during *rabi* 2021–22 and 2022–23 at Ludhiana.
SMW, Standard meteorological week; T, Temperature; RH, Relative humidity.



Meteorological parameter	Lagged Correlation Coefficients	
	2021-22	2022-23
Maximum temperature(°C)	0.95***	0.69*
Minimum temperature (°C)	0.99**	0.92**
Morning relative humidity (%)	-0.61*	-0.38
Evening relative humidity (%)	-0.30	0.01
Rainfall (mm)	-0.17	0.62*
Sunshine hours(hours)	0.53*	0.22
Wind speed (km/h)	-0.02	-0.29

*Significant at 5% level ($p \leq 0.05$)
**Significant at 1% level ($p \leq 0.015$)
***Significant at 0.1% level ($p \leq 0.001$)

Fig. 5 Weather-foliar blight window during *rabi* 2021–22 and 2022–23 at Gurdaspur.
SMW, Standard meteorological week; T, Temperature; RH, Relative humidity.

hours and wind speed exhibited inconsistent and weak lagged effects.

Correlation coefficients between meteorological parameters and foliar blight severity: It was found that maximum temperature (0.96, 0.45) and minimum temperature (0.91, 0.91) had highly significant positive correlation with foliar blight disease severity during *rabi* 2021–22 and 2022–23 at Ludhiana (Supplementary Table 3). A negative correlation between morning relative humidity and disease severity (-0.76 and -0.25) was observed during both the years. But in case of evening relative humidity, it was negatively correlated with disease severity during *rabi* 2021–22 (-0.64) but positively correlated (0.70) during *rabi* 2022–23. A significant positive correlation (0.79) between sunshine hours and disease severity was found during *rabi* 2021–22 and negatively correlated (-0.12) during *rabi* 2022–23. Rainfall (-0.40) was negatively correlated during *rabi* 2021–22 while it was positively correlated (0.7) during *rabi* 2022–23. High relative humidity encouraged the spread of the disease, especially in South Asia's intensive irrigated rice and wheat production systems, where spot blotch outbreaks were more likely to occur in locations with average temperatures over 17°C during the coolest months (Aggarwal *et al.* 2000).

At Gurdaspur, it was found that maximum temperature (0.97, 0.39) and minimum temperature (0.91, 0.95) had highly significant positive correlation coefficient with foliar blight disease severity during *rabi* 2021–22 and *rabi* 2022–23, respectively (Supplementary Table 3). A negative correlation coefficient between morning relative humidity (-0.70 and -0.12) and disease severity was observed during both the years. But in case of evening relative humidity, it was negatively correlated with disease severity during *rabi* 2021–22 (-0.86) but positively correlated (0.89) during *rabi* 2022–23. A significant positive correlation coefficient (0.55) between sunshine hours and disease severity was found during *rabi* 2021–22 and negatively correlated (-0.56) during *rabi* 2022–23. Rainfall (-0.32) was negatively correlated during *rabi* 2021–22 while it was positively correlated (0.8) during *rabi* 2022–23. Spot blotch epidemics can spread quickly under the right weather conditions, which includes five or six days of nonstop rain followed by warmer temperatures (20–30°C) (Mehta 1998). The differences in correlations between the two years can be attributed to variations in temperature, humidity, rainfall, and sunshine hours, which influenced foliar blight severity differently in 2021–22 and 2022–23. The maximum temperature was higher (28.1°C vs. 26.3°C) and fluctuated more (SD: 5.5 vs. 1.9) in 2021–22, which may have led to inconsistent disease progression. Rainfall was significantly higher in 2022–23 (8.2 mm vs. 1.9 mm in 2021–22), with greater variability (SD: 12.2 vs. 3.7). The increased moisture likely enhanced pathogen activity, resulting in a stronger correlation with disease severity. The lower rainfall in 2021–22 may have limited pathogen spread, weakening the relationship. While morning relative humidity remained similar, evening relative humidity was higher (44.6% vs. 42.7%) and more stable in 2022–23 (SD: 4.8 vs. 12.4 in 2021–22). This could have prolonged leaf wetness in 2022–23, increasing disease severity and strengthening humidity correlations.

Regression models: The regression equations developed for foliar blight severity in Ludhiana and Gurdaspur highlighted the significant role of meteorological parameters in disease progression (Supplementary Table 4). The models indicated that minimum temperature (T_{min}) was the most influential factor, consistently showing a strong positive correlation with disease severity across both locations. Higher T_{min} creates favourable night-time conditions for pathogen survival and disease development. Rainfall (RF) positively contributed to disease severity by increasing moisture availability. The effect of morning relative humidity (RHm) and evening relative humidity (RHe) varied, with RHm generally showing a weak negative effect on disease severity. The models developed for Gurdaspur have slightly higher adjusted R^2 values, suggesting that meteorological variables in this region better explained foliar blight severity compared to Ludhiana. The adjusted R^2 values improve the effect of independent variables and increase only when a new variable significantly improves the model. If an irrelevant variable is added, adjusted R^2 decreases. Among the different models, those incorporating T_{min}, rainfall and RHm appear to provide the best predictive accuracy. The suitability of these models can be assessed for real time data. Similar regression models had been developed by different researchers for wheat diseases like Sandhu *et al.* (2021) formulated a prediction model for stripe rust based on weather conditions. Anand *et al.* (2024) studied the adequacy of various methods of machine learning for weather-based prediction of Karnal bunt and found that random forest regression (RF) for February month, support vector regression (SVR) for March month, SVR and BLASSO for 15th February to 15th March period and random forest for overall period surpassed the performance than other models.

Temperature, humidity and leaf wetness affects severity of foliar blight in wheat. Early sowing dates recorded higher disease severity in the susceptible varieties under increased humidity condition. During early phase of crop, higher moisture availability with lesser sunshine hours favours foliar blight development. After rigorous analysis, it can be concluded that warm and humid weather, especially after continuous rains, favours rapid foliar blight development. The suitability of regression models can be assessed for real time data and can be used for forewarning of foliar blight in Punjab after validation.

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