



RESEARCH ARTICLE

Dynamic relationship of weather variables, transplanting time and rice blast severity in Northwestern Haryana, India

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Abstract

Rice blast, caused by the fungus *Pyricularia oryzae* Cavara, is one of the most important rice diseases worldwide. It damages plant leaves and panicles, reduces photosynthetic area and may even cause plant death. However, the disease appears only under favorable weather conditions. The present study was conducted to investigate the influence of weather factors on rice blast under field conditions. Field experiments were carried out during kharif 2022 and 2023 at Rice Research Station, RRS Kaul. Two varieties, CSR 30 and PB 1121, were transplanted on 3 dates (7th, 16th and 22nd June) under irrigated conditions. Initial leaf symptoms appeared during the final week of July or the first week of August, when the mid-tillering stage coincided with conducive environmental conditions in both years. Maximum disease progression for both leaf blast and neck blast was observed with the last date of transplanting in both years and varieties. The optimum temperature (~25 °C) and relative humidity (~92 %) were found to favor disease development. Correlation and regression analyses revealed a significant quantitative association between prevailing meteorological parameters and disease severity, indicating that weather variables collectively played a decisive role in epidemic development across both years.

Keywords: blast; *Pyricularia*; rice; temperature; weather factor

Introduction

Rice is a crucial crop in India, recognized as the primary staple in the Indian diet. India has the largest area under rice cultivation and is the second-largest producer of rice worldwide. Rice provides more calories per hectare than any other cereal food grain. Similarly, in India, rice is grown on 451.52 lakh ha, with a production of 1238.15 lakh tons and a productivity of 2742 kg/ha (1). In India, West Bengal, Uttar Pradesh, Punjab, Haryana, Tamil Nadu and Andhra Pradesh are the main states that produce rice. The market places a high value on Haryana's Basmati rice for its exceptional aroma, cooking quality and deliciousness. Haryana produces 56.43 lakh tonnes of rice annually on 15.32 lakh hectares of land, with a yield of 3683 kg/ha (2). Many bacterial, viral, fungal and nematode diseases are known to damage rice, resulting in significant losses each year across the globe. Amongst all fungal diseases, rice blast, caused by *Pyricularia oryzae*, is one of the most devastating, widely distributed and economically significant diseases of rice. Rice blast was likely the disease recognized as rice fever disease in China as early as 1637. It was referred to as Imochibyō in Japan in 1704 and brusone in Italy in 1828. It was documented in the United States as early as 1876. It was described in a study that the disease first appeared in Thanjavur delta, south India, in 1918 (3). In addition to culms and culm nodes, the pathogen causes lesions on panicle neck nodes

(neck rot), panicles (panicle blast), leaf collars (collar blast) and leaves (leaf blast), depending on age, environmental conditions and varietal resistance. These lesions vary in colour and shape. These lesions expand and merge, ultimately leading to the death of the whole leaf. Typically, leaf blast lesions are tapering and elongated at both ends, while brown spot lesions tend to be more circular and browner in appearance. "Neck blast" is the term for the condition that occurs when the node directly behind the ear head turns black. Low grain yield results from infected branches breaking off or the entire inflorescence breaking off at the rotted neck. Grains borne on such infected ears are mostly chaffy (4). The grain infection resulted in dark brown to black spots. Leaf blast causes plant stunting, resulting in less mature panicles and grain weight. Severe infections on the panicles often reduce the crop yields (5). *Pyricularia grisea* has septate, uninucleate and branched hyphae that turn brown with age. It produces sticky spore tip mucilage (STM) to attach to hosts and initiate infection. The appressoria are melanin-rich and have thickened cell walls, aiding in their nourishment from the host. *Pyricularia* is a haploid fungus that reproduces sexually and asexually, with grey conidiophores producing abundant, three-celled, pear-shaped conidia in lesions (6). When blast disease reaches epidemic proportions, yield loss can range from 30 % to 100 % (7). Particularly in upland and rain-fed areas of the tropics and subtropics, blast thrives under frequent, extended dew periods

and low daytime temperatures (8). Additionally, inadequate flooding during the planting season increases the risk of blast infection in plants (9).

The parameters significantly influence the incidence and severity of rice blast, as revealed by a study in the Jammu plains (10). Environmental dynamics and rice farming are interrelated, with weather factors such as relative humidity, rainfall, daylight hours, wind speed, maximum temperature (Tmax) and minimum temperature (Tmin) significantly influencing disease severity. Maximum temperature and Tmin significantly influence crop health because rice is susceptible to high temperatures, which affect spikelet fertility and harvest index (11, 12). Changes in humidity, rainfall and sunshine hours directly influence the severity of rice blast disease (13, 14). Selected studies have also investigated how climate change broadly influences disease patterns, particularly emphasizing the effects of temperature and rainfall on disease dynamics (15, 16). Another study provided global insight into how weather fluctuations affect rice pests and diseases, showing how they accelerate disease outbreaks and agricultural losses (17). Moreover, a separate study examined the responses of several cultivars to higher temperatures, emphasizing the influence of environmental factors on rice production (18). The pathogen is highly variable and the disease is influenced by the weather. Most farmers employ fungicidal chemicals, use resistant cultivars and refrain from overfertilizing in order to lessen the damage caused by this disease. Even with these protective measures, in certain weather conditions, rice blast causes significant losses. This is because weather affects both the parasite's reproductive capacity and the rice plant's resilience. Therefore, the relationship between the parasite and weather conditions alone cannot account for an outbreak of rice blast in a particular rice area. Therefore, the current study aimed to investigate how weather, sowing time and variety affect the disease severity index and progression.

Materials and Methods

Experimental setup

To study the effect of weather variables and different sowing time on disease progression, field experiments were conducted with two susceptible scented rice genotypes, CSR 30 and PB 1121, were transplanted in a randomized block design with 3 replications, in plots measuring 5 x 3 m, with a row to row and plant to plant spacing of 20 x 15 cm. Meteorological data were recorded using on-site automated weather instruments installed at the experimental farm. Parameters, including temperature, relative humidity and rainfall, were recorded weekly throughout the cropping season. Transplanting occurred on three different dates i.e. (D1: 9th July, 2022 and 10th July, 2023, D:2 18th July, 2022 & 2023 and D:3 24th July, 2022 and 26th July in 2023, at the research farm of RRS, Kaul (latitude of 29.857°; longitude of 76.659° and altitude: 230.7 m AMSL) during kharif seasons of 2022-23 and 2023-24. The crop was grown using the recommended set of cultivation methods. PB 1121 was selected for its widespread cultivation and economic importance in the region, whereas CSR 30 was included for its distinct physiological and stress-tolerance traits. Their contrasting disease reaction profiles allowed evaluation of varietal response across different environmental windows.

Disease assessment

Disease severity observations were documented weekly on 5 randomly selected rice hills per plot, commencing from disease onset to crop maturity, for leaf blast, utilising a 0 to 9 scale based on the lesions formed on the leaves (7) 0: Absence of observable symptoms; 1: Presence of small brown specks, ranging from pinhead size or larger, lacking a sporulating center; 2: Manifestation of small, roundish to slightly elongated necrotic grey spots, measuring approximately 1-2 mm in diameter, accompanied by a distinct brown margin, predominantly localized on lower foliar surfaces; 3: Appearance of lesions akin to those described in level 2, albeit with a notable prevalence on upper leaf regions; 4: Occurrence of characteristic blast lesions indicative of susceptibility, measuring 3 mm or longer, affecting less than 4 % of the leaf surface area; 5: Presence of typical blast lesions, encompassing 4-10 % of the leaf surface area; 6: Manifestation of typical blast lesions covering 11-25 % of the leaf surface area; 7: Presence of typical blast lesions covering 26-50 per cent of the leaf surface area ; 8 The per disease severity was calculated using standard formula (19). The data were collected from the Agrometeorology lab at the Rice Research Station, Kaul, on disease severity and meteorological parameters, including minimum and maximum temperatures, morning and evening relative humidity, rainfall (mm) and the number of rainy days.

$$\text{Percent Disease Index (PDI) (\%)} = [\sum (n \times v) / (N \times V)] \times 100 \quad (\text{Eqn. 1})$$

Where:

n = number of leaves in each disease grade

v = numerical value of disease grade

N = total number of leaves observed

V = maximum disease grade

Statistical analysis

The progression of the disease with weather parameters was analysed, namely, Tmax, Tmin, relative humidity morning (RHM) and relative humidity evening (RHE), rainfall and rainy days for different sowing environments. The correlation coefficient was calculated using OPSTAT software. Since meteorological parameters are often interrelated, multicollinearity diagnostics were performed prior to regression analysis. Variance Inflation Factor (VIF) values were calculated for Tmax, Tmin and relative humidity. All VIF values were below the critical threshold, indicating no significant multicollinearity and supporting the validity of the regression coefficients.

Correlation and regression coefficients were computed from the data and the disease's progression in relation to meteorological conditions was examined. The equation for prediction that was employed:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_6X_6 \quad (\text{Eqn. 2})$$

Where,

Y = predicted disease progression

a = intercept

b1 to b6 = regression coefficient

X1 to X6 = independent variables

X1 = Tmax (°C) X2 = Tmin (°C) X3 = RHM (%) X4 = RHE (%), X5 = PE (mm), X6 = RD

The formula given was used to determine the area under the disease progress curve (20).

$$AUDPC = \sum_{i=1}^k \frac{1}{2} (y_i + y_{i+1}) \times (t_{i+1} - t_i) \quad (\text{Eqn. 3})$$

Where k = number of successive evaluations, y_i = disease severity at time t_i , y_{i+1} = disease severity at time t_{i+1} = time when disease severity was y_i , t_{i+1} = time when disease severity was y_{i+1} .

Results

Progression of leaf blast in CSR 30 and PB 1121 during kharif 2022

The progression of blast disease in rice was studied in 2 varieties, CSR 30 and PB 1121, on three dates across two kharif seasons, 2022 and 2023. On the first, second and third transplanting dates, leaf blast incidence was observed in the second week of August in both varieties during kharif 2022. The disease progressed gradually during August in all dates of transplanting (Fig. 1). In variety CSR 30, the highest disease progression was noted on 17th September 2022, with a maximum temperature of 33.6 °C, a minimum temperature of 24.9 °C, a relative humidity (morning) of 96 % and a relative humidity (evening) of 87 %. A similar pattern was observed in PB 1121. After that, a decline in disease was observed during the last week of September. Weekly disease progression % ranged from 21.27–73.14 % for CSR 30 and from 19.22–64.67 % for PB 1121 on the first date of transplanting. For the second transplanting date, the progression ranged from 16.82 to 84.56, from 16.92 to 68.25 % in PB 1121 and from 16.92 to 68.25 % in CSR 30. At the third transplanting date, the progression figures ranged from 12.28 % to 89.12 % for CSR 30 and from 11.92 % to 73.56 % for PB 1121. The highest disease index values were observed in crops transplanted during the last week of July, with CSR 30 having a PDI of 89.12 % and PB 1121 a PDI of 73.56 %. Of the 2 varieties evaluated, CSR 30 exhibited greater susceptibility compared to PB 1121.

Progression of neck blast in CSR 30 and PB 1121 during kharif 2022

After the leaf blast phase, the pathogen targets the panicle. Panicle initiation began in the third week of September. For plants transplanted on the first date, neck blast incidence was noted in the first week of October. In contrast, for those transplanted on the second and third dates, neck blast incidence was observed in the third week of October (Fig. 2).

The disease increased progressively each week (Fig. 2). The weekly disease progression ranged from 8.5 % to 84.2 % for CSR 30 and from 7.98 % to 70.92 % for PB 1121 on the first date of transplanting. For the second transplanting, the progression ranged from 4.89 to 84.6 % in CSR 30 and from 5.12 % to 73.92 % in PB 1121. On the third transplanting date, the progression ranged from 7.38 % to 89.8 % for CSR 30 and from 6.85 % to 77.89 % for PB 1121. The highest incidence of neck blast was observed in crops transplanted in the last week of July, at 89.8 % in CSR 30 and 77.89 % in PB 1121.

Progression of leaf blast in CSR 30 and PB 1121 during kharif 2023

Similarly, in the kharif season of 2023, leaf blast incidence was first observed in the 2nd week of August across all transplanting dates and in both varieties. Also, in the crops sown on the second and third transplanting dates, disease incidence was observed in the second week of August in both varieties. The disease progressed steadily throughout August across all transplanting dates for both varieties (Fig. 3).

In the variety CSR 30, the highest disease progression was noted on September 15th, 2023, with a maximum temperature of 33.9 °C, a minimum temperature of 25 °C, relative humidity (morning) of 94 % and relative humidity (evening) of 74 %. A similar pattern was also observed in PB 1121. This year, a decline in disease was observed during the last week of September. Weekly disease

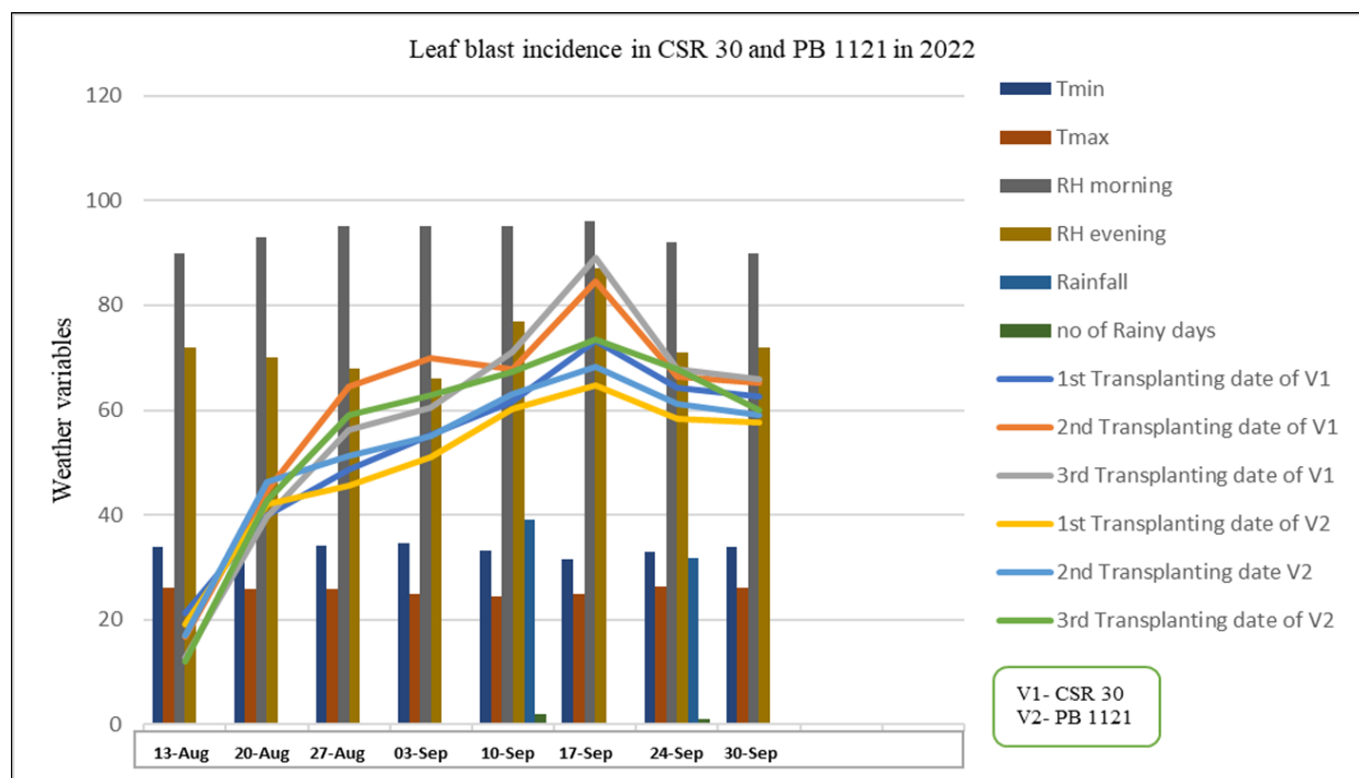


Fig. 1. Relationship between leaf blast severity and weather variables on different dates of sowing in varieties (CSR 30 and PB 1121) during kharif 2022.

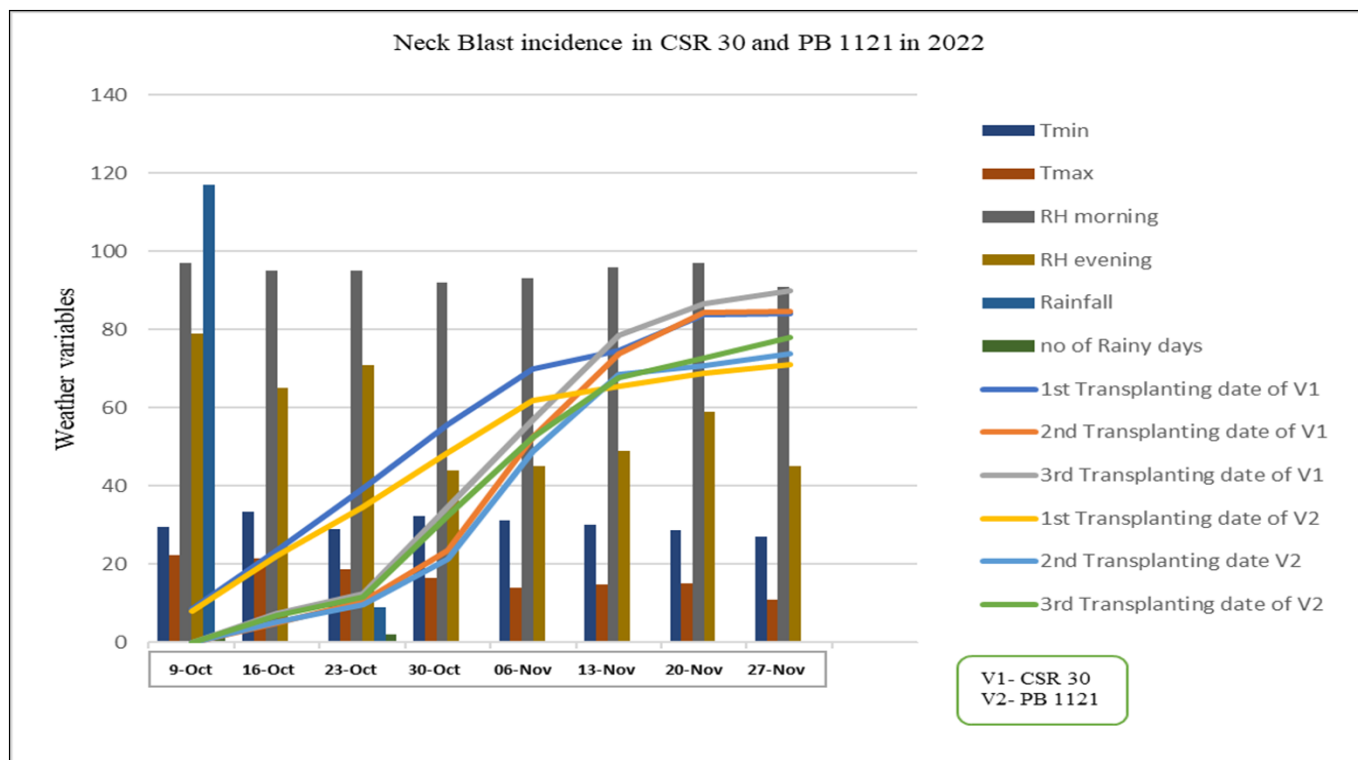


Fig. 2. Relationship between neck blast severity and weather variables on different dates of sowing in varieties (CSR 30 and PB 1121) during kharif 2022.

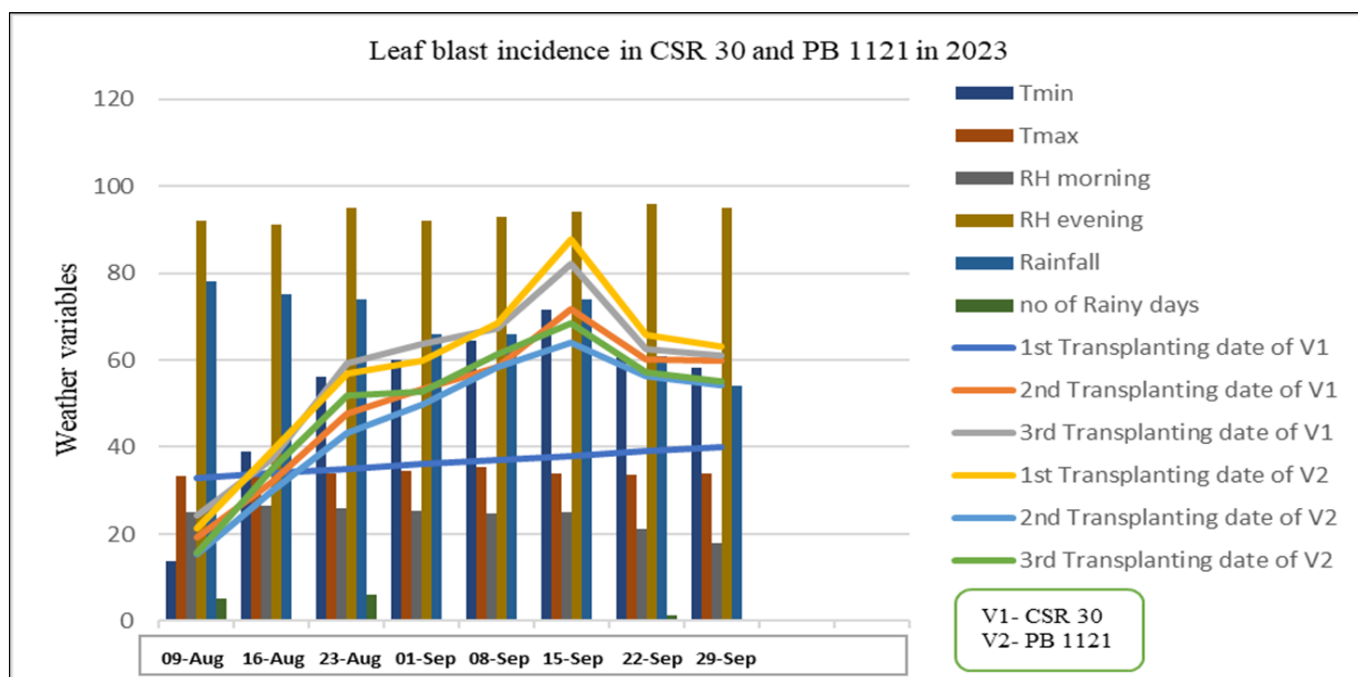


Fig. 3. Relationship between leaf blast severity and weather variables on different dates of sowing in varieties (CSR 30 and PB 1121) during kharif 2023.

progression % ranged from 19.14 % to 71.65 % for CSR 30 and from 15.34 % to 63.89 % for PB 1121 on the first date of transplanting. For the second transplanting date, the progression ranged from 24.32 % to 82.24 % in CSR 30 and from 15.72 % to 68.57 % in PB 1121. At the third transplant date, the progression figures were between 21.27 % and 87.62 % for CSR 30 and between 13.77 % and 71.82 % for PB 1121. The highest disease index values were observed in crops transplanted during the last week of July, with CSR 30 having a PDI of 87.62 % and PB 1121 a PDI of 71.42 %.

Progression of neck blast in CSR 30 and PB 1121 during kharif 2023

In season 2023, a similar trend of panicle blast was observed as that of season 2022. For plants transplanted on the first date, neck blast incidence was noted in the first week of October. While for those transplanted on the second and third dates, neck blast incidence was observed in the second week of October (Fig. 4). Weekly disease progression ranged from 7.98 % to 81.23 % for CSR 30 and from 7.23 % to 71.48 % for PB 1121 on the first transplanting date. For the second transplanting date, progression ranged from 5.02 % to 85.62 % in CSR 30 and from 4.89 % to 74.05 % in PB 1121. At the third transplanting date, progression ranged from 6.89 % to 89.34 % for CSR 30 and from 7.56 % to 78.23 % for PB 1121. The incidence of neck blast was observed in crop transplanted in the last week of

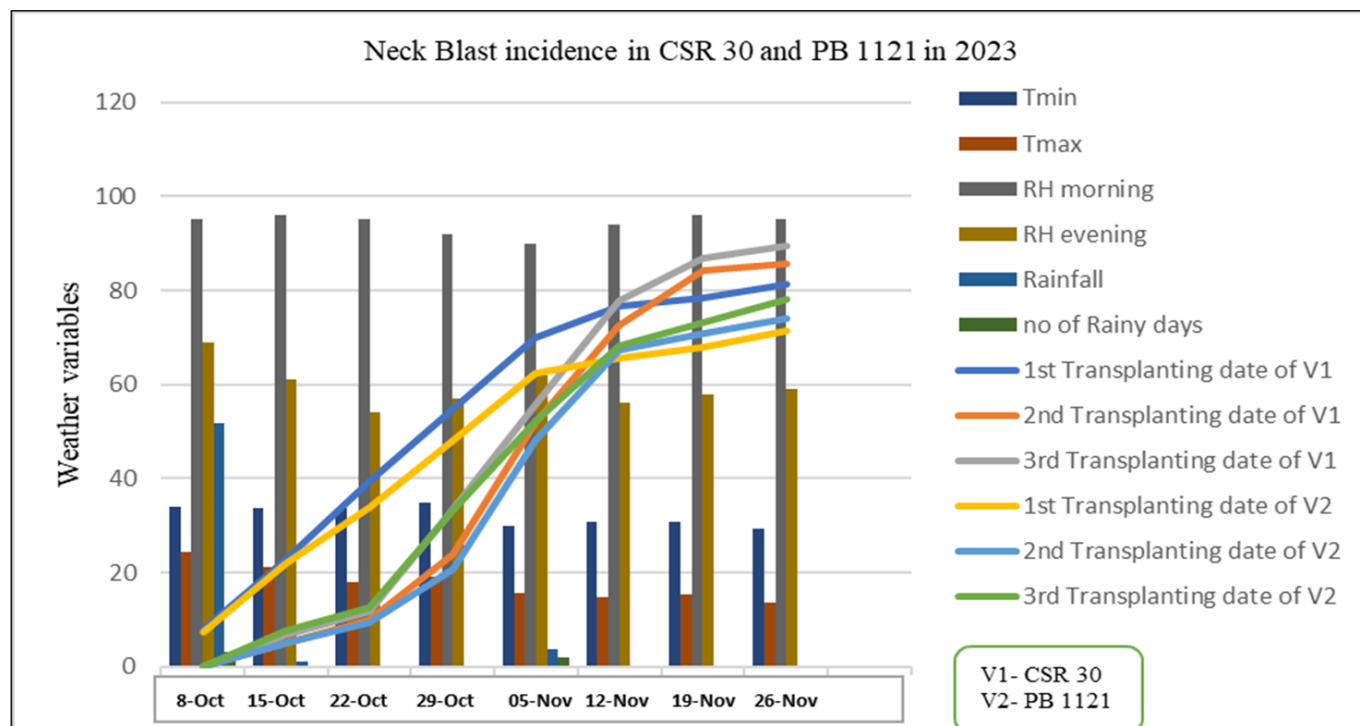


Fig. 4. Relationship between neck blast severity and weather variables on different dates of sowing in varieties (CSR 30 and PB 1121) during kharif 2023.

July, with PDI value of 89.34 % in CSR 30 and 78.23 % in PB

Effect of different dates of transplanting on Area Under Disease Progress Curve on leaf blast during kharif 2022 in variety CSR 30 and PB 1121

The disease progression over time was also computed using Area Under Disease Progress Curve (AUDPC), as shown in Table 1. The maximum AUDPC (560.84) was found in 3rd date of transplanting followed by 2nd date of transplanting (533.68) and 1st date of transplanting (488.80) on 37th Standard Meteorological Week (SMW) in CSR 30 variety and in PB 1121, maximum AUDPC (494.69) was found in 3rd date of transplanting followed by 2nd date of transplanting (533.68) and 1st date of transplanting (488.80) in 37th SMW. The value of AUDPC with respect to the average of 3 transplanting dates was maximum (522.25) on 37th SMW and minimum (203.98) on 33rd SMW in CSR 30 and in PB 1121, maximum (463.67) on 37th SMW and minimum (208.97) on 33rd SMW. The total mean AUDPC with respect to the average of 3 dates of transplanting was recorded as 3360.90 from 33-40 SMW in CSR 30 and 3101.05 in PB 1121 variety. Based on the disease progression, AUDPC was statistically analysed and it was found that the value of

AUDPC was lowest in the crop transplanted on 9th July, 2022 (3129.32.50) while it was maximum in the crop transplanted on 18th July, 2022 (3528.21) in CSR 30 variety and lowest (3094.35) on 9th July, 2022 and maximum (3286.57) on 18th July, 2022 in PB 1121 variety.

In 2023, for leaf blast maximum AUDPC (546.42) was found in 3rd date of transplanting followed by 2nd date of transplanting (523.43) and 1st date of transplanting (461.58) on 37th SMW in CSR 30 variety and in PB 1121, maximum AUDPC (475.40) was found in 3rd date of transplanting followed by 2nd date of transplanting (454.37) and 1st date of transplanting (428.12) in 37th SMW. The value of AUDPC with respect to the average of 3 dates of transplanting was maximum (508.17) on 37th SMW and minimum (201.71) in 33rd SMW in CSR 30 and in PB 1121, maximum (452.63) in 37th SMW and minimum (173.19) in 33rd SMW (Table 2). The total mean AUDPC with respect to the average of 3 dates of transplanting was recorded as 3218.47 from 33-40 SMW in CSR 30 and 2916.30 in PB 1121 variety. Based on the disease progression, AUDPC was statistically analysed and it was found that the value of AUDPC was lowest in the crop transplanted on 10th July, 2022 (2951.06) while it was

Table 1. Effect of different dates of transplanting on Area Under Disease Progress Curve on leaf blast during kharif 2022 in variety CSR 30 and PB 1121

Dates of observations	Standard meteorological weeks	AUDPC (leaf blast)							Mean
		CSR 30			Mean $\pm$ SE	PB 1121			
		Dates of transplanting				Dates of transplanting			
		09 July	18 July	24 July		09 July	18 July	24 July	
13-08-2022	33	213.82	214.90	183.23	203.98 $\pm$ 10.38	214.41	221.06	191.45	208.97 $\pm$ 9.09
20-08-2022	34	309.33	381.99	335.97	342.43 $\pm$ 21.21	306.6	340.97	356.405	334.66 $\pm$ 14.72
27-08-2022	35	363.27	470.68	409.12	414.36 $\pm$ 31.12	337.68	372.19	426.895	378.92 $\pm$ 25.96
03-09-2022	36	409.54	482.44	460.92	450.97 $\pm$ 21.63	388.745	413.63	455.91	419.43 $\pm$ 19.61
10-09-2022	37	472.22	533.68	560.84	522.25 $\pm$ 26.21	436.87	459.445	494.69	463.67 $\pm$ 16.82
17-09-2022	38	480.80	528.57	549.15	519.51 $\pm$ 20.24	430.535	452.795	493.15	458.83 $\pm$ 18.33
24-09-2022	39	444.08	460.53	467.85	457.49 $\pm$ 7.03	406.035	420.84	447.65	424.84 $\pm$ 12.18
30-09-2022	40	436.28	455.42	458.12	449.94 $\pm$ 6.88	401.345	413.42	420.42	411.73 $\pm$ 5.57
Mean		3129.32	3528.21	3425.17	3360.90 $\pm$ 119.53	2922.22	3094.35	3286.57	3101.05 $\pm$ 105.42

Values are expressed as mean $\pm$ standard error (SE) (n = 3).

Table 2. Effect of different dates of transplanting on Area Under Disease Progress Curve on leaf blast during kharif 2023 in variety CSR 30 and PB 1121

Dates of observations	Standard meteorological weeks	AUDPC (leaf blast)							Mean
		CSR 30			Mean	PB 1121			
		Dates of transplanting				Dates of transplanting			
		10 July	18 July	26 July		10 July	18 July	26 July	
09-08-2023	33	178.71	215.60	210.81	201.71 ± 11.53	158.30	176.96	184.31	173.19 ± 7.60
16-08-2023	34	278.85	337.82	334.99	317.22 ± 19.40	255.85	303.62	332.53	297.34 ± 22.14
23-08-2023	35	354.24	430.36	408.00	397.53 ± 22.46	325.11	366.41	406.91	366.15 ± 23.75
01-09-2023	36	390.99	458.61	449.12	432.91 ± 21.11	378.38	399.10	435.92	404.47 ± 16.91
08-09-2023	37	454.65	523.43	546.42	508.17 ± 27.38	428.12	454.37	475.40	452.63 ± 13.67
15-09-2023	38	461.58	506.45	536.90	501.64 ± 22.11	420.80	440.05	462.35	441.07 ± 11.99
22-09-2023	39	419.93	432.50	451.36	434.60 ± 9.15	387.48	393.33	416.18	399.00 ± 8.89
29-09-2023	40	412.13	423.89	438.13	424.72 ± 7.59	372.29	378.77	396.30	382.46 ± 7.11
Mean		2951.06	3328.64	3375.72	3218.47 ± 134.27	2726.36	2912.63	3109.92	2916.30 ± 111.07

maximum in the crop transplanted on 18th July, 2022 (3375.72) in CSR 30 variety and lowest (2726.36) on 10th July, 2022 and maximum (3109.63) on 26th July, 2022 in PB 1121 variety.

Effect of different dates of transplanting on Area Under Disease Progress Curve on neck blast during kharif 2022 in variety CSR 30 and PB 1121

The disease progression over time was also computed using AUDPC, as shown in Table 3. The maximum AUDPC (629.30) was found in 3rd date of transplanting followed by 2nd date of transplanting (593.60) and 1st date of transplanting (592.20) on 37th SMW in CSR 30 variety and In PB 1121, maximum AUDPC (545.61) was found in 3rd date of transplanting followed by 2nd date of transplanting (517.72) and 1st date of transplanting (496.72) in 48th SMW. The value of AUDPC with respect to the average of 3 transplanting dates was maximum (605.03) on 48th SMW and minimum (51.53) on 41st SMW in CSR 30 and in PB 1121, maximum (520.02) on 48th SMW and minimum (49.21) on 41st SMW. The total mean AUDPC with respect to the average of 3 dates of transplanting was recorded as 2951.53 from 41-48 SMW in CSR 30 and 2585.40 in PB 1121 variety.

PB 1121 variety. Based on the disease progression, AUDPC was statistically analysed and it was found that the value of AUDPC was lowest in the crop transplanted on 18th July, 2022 (2635.29) while it was maximum in the crop transplanted on 9th July, 2022 (3342.15) in CSR 30 variety and lowest (2346.61) on 18th July, 2022 and maximum (2885.47) on 18th July, 2022 in PB 1121 variety.

Similarly in 2023, the maximum AUDPC (627.69) was found in 3rd date of transplanting followed by 2nd date of transplanting (600.67) and 1st date of transplanting (570.89) on 37th SMW in CSR 30 variety and In PB 1121, maximum AUDPC (549.92) was found in 3rd date of transplanting followed by 2nd date of transplanting (521.29) and 1st date of transplanting (502.18) in 48th SMW. The value of AUDPC with respect to the average of 3 dates of transplanting was maximum (599.75) on 48th SMW and minimum (49.91) in 41st SMW in CSR 30 and in PB 1121, maximum (524.46) in 48th SMW and minimum (48.48) in 41st SMW (Table 4). The total mean AUDPC with respect to the average of 3 dates of transplanting was recorded as 2951.53 from 41-48 SMW in CSR 30 and 2585.40 in PB 1121 variety. Based on the disease progression, AUDPC was statistically analysed and it was found that the value of AUDPC was lowest in the crop

Table 3. Effect of different dates of transplanting on Area Under Disease Progress Curve on neck blast during kharif 2022 in variety CSR 30 and PB 1121

Dates of observations	Standard meteorological weeks	AUDPC (neck blast)							
		CSR 30			Mean	PB 1121			Mean
		Dates of transplanting				Dates of transplanting			
		09 July	18 July	24 July		09 July	18 July	24 July	
09-10-2022	41	111.65	17.12	25.83	51.53 ± 3.02	105.73	17.92	23.97	49.21 ± 27.94
16-10-2022	42	219.10	53.20	69.06	113.79 ± 52.27	199.39	51.41	64.43	105.08 ± 46.14
23-10-2022	43	332.15	118.79	164.05	205.00 ± 63.62	291.51	108.25	154.03	184.60 ± 55.62
30-10-2022	44	439.25	266.14	319.69	341.69 ± 52.29	386.26	245.49	296.8	309.52 ± 41.51
06-11-2022	45	505.05	442.09	473.41	473.52 ± 18.18	445.79	411.00	420.10	425.63 ± 10.69
13-11-2022	46	554.40	553.46	578.03	561.96 ± 7.88	470.64	488.18	491.71	483.51 ± 6.61
20-11-2022	47	588.35	590.91	617.79	599.02 ± 8.90	489.40	506.62	527.45	507.82 ± 11.05
27-11-2022	48	592.20	593.60	629.30	605.03 ± 11.68	496.72	517.72	545.61	520.02 ± 14.14
Mean		3342.15	2635.29	2877.14	2951.53 ± 206.37	2885.47	2346.61	2524.13	2585.40 ± 159.71

Table 4. Effect of different dates of transplanting on Area Under Disease Progress Curve on neck blast during Kharif 2023 in variety CSR 30 and PB 1121

Dates of observations	Standard meteorological weeks	AUDPC (neck blast)							Mean
		CSR 30			PB 1121				
		Dates of transplanting			Mean	Dates of transplanting			
		09 July	18 July	24 July		09 July	18 July	24 July	
08-10-2023	41	108.05	17.57	24.12	49.91 ± 29.65	101.85	17.115	26.46	48.48 ± 26.11
15-10-2023	42	217.60	52.19	65.59	111.79 ± 49.69	195.265	50.435	70.035	105.25 ± 43.77
22-10-2023	43	329.35	118.76	158.55	202.22 ± 61.70	287.14	106.19	159.495	184.28 ± 53.66
29-10-2023	44	437.05	265.72	312.31	338.36 ± 50.37	386.26	241.29	298.725	308.76 ± 42.00
05-11-2023	45	513.56	435.96	467.25	472.26 ± 22.44	447.16	403.76	421.33	424.08 ± 12.58
12-11-2023	46	542.96	549.26	575.61	555.94 ± 10.04	466.935	483.56	494.305	481.60 ± 7.99
19-11-2023	47	558.88	594.55	616.28	589.90 ± 16.78	487.795	507.395	529.585	508.26 ± 12.10
26-11-2023	48	570.89	600.67	627.69	599.75 ± 16.58	502.18	521.29	549.92	524.46 ± 13.99
	Mean	3278.31	2634.66	2847.39	2920.12 ± 189.42	2874.58	2331.05	2549.85	2585.16 ± 157.15

Table 6. Correlation of weather variables and date of sowing on rice neck blast in rice variety CSR 30 AND PB 1121

Weather variables	CSR 30										PB 1121				
	Date of transplanting 2022					Date of transplanting 2023					Date of transplanting 2022				
	09-07-22	09-07-22	09-07-22	09-07-22	09-07-22	Overall	10-07-23	18-07-23	26-07-23	Overall	09-07-22	18-07-22	24-07-22	Overall	Overall
Temperature max.	-0.481	-0.471	-0.471	-0.471	-0.471	-0.549	-0.778	-0.891	-0.894	-0.854	-0.471	-0.581	-0.547	-0.533	-0.852
Temperature min.	-0.970	-0.973	-0.973	-0.973	-0.973	-0.930	-0.974	-0.945	-0.956	-0.958	-0.973	-0.907	-0.937	-0.939	-0.959
Relative humidity (morning)	-0.493	-0.511	-0.511	-0.511	-0.511	-0.381	-0.437	-0.301	-0.333	-0.357	-0.511	-0.309	-0.389	-0.403	-0.361
Relative humidity (evening)	-0.866	-0.875	-0.875	-0.875	-0.875	-0.779	-0.88	-0.801	-0.811	-0.831	-0.875	-0.729	-0.792	-0.799	-0.825
Rainfall	-0.781	-0.791	-0.791	-0.791	-0.791	-0.663	-0.888	-0.733	-0.761	-0.794	-0.791	-0.598	-0.647	-0.679	-0.803
Rainy days	-0.763	-0.776	-0.776	-0.776	-0.776	-0.724	-0.833	-0.737	-0.733	-0.768	-0.776	-0.695	-0.738	-0.736	-0.775

Table 7. Multiple regression equation for the prediction of progressive blast disease in different dates of transplanting of CSR 30 and PB 1121 variety in relation to weather parameters (2022 & 2023)

Date of transplanting	Regression equations (2022)	Regression equations (2023)	R ² value (2022)	R ² value (2023)
09-07-2022	Y= 1716.14 - 28.88 X ₁ - 5.93 X ₂ - 3.22 X ₃ - 3.29 X ₄ + 0.036 X ₅ - 13.25 X ₆	Y= 618.06 - 5.46 X ₁ - 13.46 X ₂ + 1.74 X ₃ - 2.88 X ₄ - 1.09 X ₅ + 30.41 X ₆	0.92	0.96
18-07-2022	Y= 2009.11 - 36.45 X ₁ - 6.17 X ₂ - 1.95 X ₃ - 5.17 X ₄ - 0.023 X ₅ - 14.22 X ₆	Y= 616.39 - 5.16 X ₁ - 14.42 X ₂ + 2.87 X ₃ - 4.04 X ₄ - 1.04 X ₅ + 32.53 X ₆	0.93	0.93
24-07-2022	Y= 2141.00 - 37.30 X ₁ - 8.74 X ₂ - 2.24 X ₃ - 5.33 X ₄ - 0.058 X ₅ - 13.76 X ₆	Y= 737.81 - 6.22 X ₁ - 16.94 X ₂ + 2.78 X ₃ - 4.32 X ₄ - 1.128 X ₅ + 38.24 X ₆	0.95	0.92
10-07-2022	Y= 1376.08 - 26.66 X ₁ - 0.37 X ₂ - 1.99 X ₃ - 3.17 X ₄ + 0.07 X ₅ - 12.24 X ₆	Y= 539.94 - 1.96 X ₁ - 13.94 X ₂ + 0.97 X ₃ - 2.28 X ₄ - 0.85 X ₅ + 21.31 X ₆	0.95	0.96
18-07-2022	Y= 2332.19 - 38.45 X ₁ - 3.78 X ₂ - 6.78 X ₃ - 3.52 X ₄ + 0.02 X ₅ - 18.91 X ₆	Y= 466.03 - 0.176 X ₁ - 15.31 X ₂ + 1.55 X ₃ - 2.49 X ₄ - 0.68 X ₅ + 17.23 X ₆	0.94	0.92
26-07-2022	Y= 2765.87 - 45.45 X ₁ - 3.69 X ₂ - 8.52 X ₃ - 4.03 X ₄ - 0.01 X ₅ - 20.34 X ₆	Y= 490.59 - 0.731 X ₁ - 15.13 X ₂ + 2.29 X ₃ - 3.43 X ₄ - 0.66 X ₅ + 20.96 X ₆	0.95	0.91

combined effects of maximum and minimum temperatures and morning and evening relative humidity accounted for 96 and 91 % of the prediction of neck blast disease progression in CSR 30 and PB 1121, respectively (Table 7).

A similar trend was observed in kharif 2023 for both varieties, with highly significant equations ($R^2 = 0.93$ and 0.94 for leaf blast and $R^2 = 0.930$ and 0.927 for neck blast) for CSR 30 and PB 1121, respectively.

Discussion

In the current investigation, 3 dates were used to transplant 2 susceptible varieties, CSR 30 and PB 1121, i.e., the first, second and last weeks of July during the Kharif 2022 and 2023 seasons. The study found that crops transplanted in the last week of July exhibited higher disease severity of both leaf and neck blast than those transplanted earlier in both years. Similar results were reported in a study, which noted a negative relationship between transplanting date and disease severity (21). Their results showed that earlier-transplanted crops suffered less severe disease than later-transplanted crops. The disease continued to advance steadily throughout August. The morning's relative humidity and minimum temperature were both close to the optimal range, with the former ranging between 25 °C and 28 °C and the latter between 89 to 95 %. Across all three transplanting dates in both years, CSR 30 exhibited a higher incidence of disease than PB 1121, as indicated by the disease progression data. These results were similar to those of a previous study, which investigated how various meteorological conditions affect the rice blast fungus and identified relationships among temperature, relative humidity, precipitation and sunshine hours for forecasting disease progression (21). They found that the best conditions were T_{max} of 26–28 °C and a minimum relative humidity of 60 %–70 % and that larger spore populations formed 3–5 days after precipitation events. The disease index was negatively correlated with maximum temperature, minimum temperature, rainfall and the number of rainy days, based on combined leaf blast data from three transplanting dates in both years. Both morning and evening relative humidity were positively correlated with the per cent disease index in both years. According to the best-fitting multiple regression models, the combined effects of rainy days, evening relative humidity and maximum and minimum temperatures might account for 91 %–96 % of the variance in the progression of leaf blast disease in PB 1121 and CSR 30, respectively. The pooled analysis of neck blast data showed that the number of rainy days, rainfall, evening relative humidity, maximum temperature and minimum temperature were negatively correlated in both years. These findings coincide with those of another investigation, which found that the onset of disease was positively correlated with relative humidity and negatively correlated with maximum temperature (22). Their regression model explained 96 % of the variability in disease progression. Similarly, another study reported a strong correlation between disease progression and cloud cover and minimum temperature (23). During the kharif seasons of 2022 and 2023, multiple regression analyses were conducted to model disease severity in the rice cultivars CSR 30 and PB 1121. For both cultivars, highly significant regression models were created for both leaf and neck blast and in every instance, the R^2 values were greater than 0.92. The leaf blast models showed strong

forecasting capacity in kharif 2022, accounting for 96 % of the variation in disease progression for CSR 30 and 91 % for PB 1121.

Similarly, neck blast models showed significant predictive accuracy, explaining 91 % and 96 % of the variation in disease progression for PB 1121 and CSR 30, respectively. These results indicated that morning and evening relative humidity, along with maximum and minimum temperatures, are important factors in determining disease severity across both cultivars and disease types. The robustness and dependability of these regression models for forecasting disease progression in these rice varieties are further highlighted by consistently high R^2 values seen in both years and cultivars.

The epidemiological trends of rice blast observed in Haryana are broadly consistent with reports from other rice-growing agro-climatic zones. Previous studies across diverse ecological regions have demonstrated that temperature and relative humidity are primary drivers of blast development, resulting in marked spatial and temporal variability in disease severity. The present findings corroborate these observations, confirming the strong influence of meteorological parameters on epidemic progression. Although absolute severity levels vary across regions due to local climatic and varietal factors, the overall disease-weather relationship aligns with established patterns in global rice blast epidemiology, thereby reinforcing the study's external validity.

Disease progression over time was also computed using AUDPC, with the maximum AUDPC observed on the 3rd date of transplanting, followed by the 2nd and 1st dates of transplanting in the CSR 30 and PB 1121 varieties across both years. Based on disease progression, AUDPC was statistically analysed and it was found that the value of AUDPC was lowest in the early-transplanted crop and highest in the late-transplanted crop in both CSR 30 and PB 1121 across both years.

Conclusion

The results confirm that rice blast epidemiology is stage-specific and strongly modulated by microclimatic conditions. Relative humidity emerged as the principal driver of leaf blast development, while neck blast showed a contrasting weather-disease relationship. The consistent increase in disease severity under delayed transplanting underscores the vulnerability of late-sown crops to favorable epidemic conditions. Therefore, optimising transplanting time represents a viable cultural strategy to mitigate blast risk under north Indian agro-ecological conditions.

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Authors' contributions

A and AK conceptualized and designed the study. MSB, JM and SS conducted the field experiments. P and ASC supervised the research. ASC, LY, AKS and A carried out the data analysis and

handled software-related tasks. AKS, SS and A drafted the original manuscript. P, AK, JM and LY contributed to revising and finalizing the manuscript. All authors read and approved the final version.

Compliance with ethical standards

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