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WEATHER-DRIVEN EPIDEMIOLOGY OF RICE SHEATH BLIGHT (*RHIZOCTONIA SOLANI* KÜHN): EFFECTS OF TRANSPLANTING DATE AND ENVIRONMENTAL FACTORS ON DISEASE DEVELOPMENT

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ABSTRACT

Sheath blight, caused by Rhizoctonia solani Kühn, is one of the most destructive diseases affecting rice production under intensive cultivation. A field study was conducted to evaluate the influence of weather parameters on sheath blight development under different transplanting dates. Disease observations were recorded in a Disease Observation Nursery (DON) using the susceptible rice cultivar 'Swarna'. Three transplanting dates (early, mid, and late) were evaluated, and disease severity was assessed weekly using the IRRI Standard Evaluation System (0–9 scale). Meteorological variables including temperature, relative humidity, rainfall, and bright sunshine hours were correlated with disease progression. Disease initiation occurred during the 33rd, 37th, and 40th Standard Meteorological Weeks (SMW) in early-, mid-, and late-transplanted crops, respectively. Maximum cumulative disease severity reached 33.8, 26.6, and 31.1% during 2022 and 36.6, 28.3, and 33.3% during 2023 in early-, mid-, and late-transplanted crops, respectively. Disease development was favored by maximum temperatures of 30–34°C, morning relative humidity above 88%, and frequent rainfall during the tillering stage. Correlation analysis indicated a positive association of disease severity with maximum temperature ($r = 0.16–0.57$), bright sunshine hours ($r = 0.43–0.74$), and morning relative humidity, while minimum temperature ($r = −0.65$ to $−0.86$), evening relative humidity ($r = −0.61$ to $−0.79$), and rainfall ($r = −0.31$ to $−0.50$) were negatively correlated with disease severity. The study demonstrates that early transplanting synchronized susceptible crop stages with favorable weather, resulting in greater sheath blight severity. These findings provide valuable information for disease forecasting and optimizing transplanting schedules for integrated sheath blight management.

KEYWORDS: Rhizoctonia solani, rice sheath blight, disease epidemiology, transplanting date, weather parameters

INTRODUCTION

Rice (*Oryza sativa L.*) is the most staple food for more than half of the world's population and plays an important role in global food and nutritional security (Asanteet al., 2025). India is one of the world's leading rice-producing countries, where the crop contributes substantially to national food security, rural livelihoods, and the agricultural economy (Asanteet al., 2025). However, sustainable rice production is continuously challenged by several fungal, bacterial, and viral diseases that significantly reduce grain yield and quality. Among these, sheath blight caused by Rhizoctonia solani Kühn (teleomorph: Thanatephoruscucumeris) has emerged as one of the most destructive diseases in rice production systems owing to the widespread cultivation of high-yielding, susceptible cultivars, dense planting, and intensive nitrogen fertilization (Li et al., 2021).

The disease is also called “snake skin disease”, “mosaic foot stalk”, and “rotten foot stalk” because of its special disease symptoms (Molla et al. 2020;Zhang et al. 2019). Rice sheath blight occurs in nearly all rice-growing countries and is considered the second most economically important rice disease after blast. Depending on cultivar susceptibility, environmental conditions, crop management practices, and disease intensity, yield losses may range from 5 to 50% or even higher under highly conducive environments (Singh et al. 2019;Ghosh et al. 2025).

Disease development is governed by complex interactions among the host, pathogen, and environment. The disease generally initiates during the maximum tillering stage when lower leaf sheaths remain in proximity to the soil surface, facilitating infection by soil-borne inoculum. Thereafter, rapid disease progress depends on canopy microclimate, particularly prolonged leaf wetness, high relative humidity, warm temperatures, and dense crop canopy, which promote mycelial growth and repeated secondary infections. Several investigators have reported that temperatures between 30 and 34°C, relative humidity exceeding 90%, and extended canopy wetness provide optimum conditions for disease establishment and epidemic development (Singh et al. 2019;Molla et al. 2020; Ghosh et al. 2025).

Crop establishment time is another important determinant of sheath blight epidemiology because transplanting date influences the synchronization between susceptible crop growth stages and prevailing environmental conditions. Early, medium, and late transplanting expose the crop to different combinations of temperature, rainfall, humidity, and solar radiation during tillering and panicle initiation, thereby affecting disease onset, epidemic development, and final disease severity (Ahamad et al. 2023).

Although considerable progress has been made in understanding the biology, host–pathogen interactions, and management of R. solani, quantitative information on weather-driven disease progression under different transplanting windows remains limited for the rice-growing ecosystems of central India, particularly the Chhattisgarh plains. Such information is essential for improving epidemiological models, developing weather-based disease forewarning systems, and identifying appropriate crop establishment schedules that reduce disease risk. Therefore, the present investigation was conducted during the kharif seasons of 2022 and 2023 under natural epiphytotic conditions to evaluate the temporal development of rice sheath blight under early, mid-, and late-transplanting dates (Li et al. 2021).

MATERIAL AND METHOD

Experimental site

A field trial was conducted during the kharif 2022 and 2023 at I.G.K.V. Raipur research farm on a bunded rice field under natural conditions.

Experimental Design

The experiments were conducted in a randomized complete block design (RCBD) and various treatments with three replications. Critical difference using at $p<0.05$ level of significance (Gomez and Gomez 1984). Statistical analysis was carried out by using R Studio package.

Influence of environmental factors on disease progress and severity of Rhizoctonia solani of rice was studied in two successive seasons under Disease Observation Trap Crop Nursery (DON) in early, mid and late conditions oncultivar “Swarna” with plot size of 20 × 3.0 m2. No plant protection measures were taken up in this plot.

The weekly observations on weather parameters viz., maximum temperature (ºC), minimum temperature (ºC), morning relative humidity (%), evening relative humidity (%), sunshine hours per day, rainfall (mm) and wind speed (km/hr) were recorded from the meteorological observatory of I.G.K.V. Raipur during Kharif 2022 and 2023. The averages of the meteorological week (MW) wise weather parameters with the average disease incidence during period of experimentation were used in the correlation. In field 1m square area was select, initially the rice plants were observed daily for the appearance of sheath blight disease. The rice plants on which the sheath blight disease appeared were tagged for further periodical observation. Likewise, the observations were made for sheath blight disease incidence and its intensity from the first appearance of disease till the physiological maturity of the crop at weekly intervals. Percent disease incidence (PDI) was calculated using the following formula as described by (Mayee and Datar 1986):

Percent disease incidence

$$\textbf{Percent disease incidence} = \frac{\text{Number of diseased plant}}{\text{Total number of plants observed}} \text{X } 100$$

Percent disease severity

Disease severity was assessed using the appropriate disease rating scale (0-9), and the PercentDisease Severity (PDS) [also referred to as Percent Disease Index (PDI)] was calculated according to the method of Wheeler (Wheeler 1969) using the following formula:

$$\textbf{Percent disease severity} = \frac{\text{Sum of the individual disease ratings}}{\text{Total number of plants observed} \times \text{Maximum grade}} \text{X } 100$$

Correlation matrix studies were carried out to determine the relationships between weather parameters and sheath blight disease with progressive per cent disease incidence based onthe following formula:

$$r = \frac{cov\ (X,Y)}{\sigma x \times \sigma y} = \frac{\sum_{i=1}^{n}(X-\bar{X})}{\sqrt{\sum_{i=1}^{n}(X-\bar{X})^2 * \sqrt{\sum_{i=1}^{n}(Y-\bar{Y})^2}}}$$

Where,

X = Mean of first factor

Y = Mean of second factor

n = Total no. of observations
r = Correlation coefficient

In the present investigation, we studied the effect of dates of transplanting (Early, Medium and Late) on sheath blight disease progression. Disease in the experimental plots developed from the natural inoculum in the field. In early transplanted rice, the disease observation was recorded on 13–19 August. By this time, the crop was at maximum tillering phase. The date of observation i.e., 13–19 August, is the 33rd standard meteorological week.

Test of significance of correlation coefficient:
The test of significance of the correlation coefficient means testing the hypothesis whether or not the correlation coefficient is zero in the population that we test (Gomez and Gomez 1984).
H: = ρ = 0 vs. H1: ρ ≠ 0

Test statistics $t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$

Where,
t = test of significance
r = correlation coefficient
n = number of observations

RESULT

Temporal Disease Progression and Epidemic Onset across Transplanting Dates

The temporal development and final severity of rice sheath blight, caused by Rhizoctonia solani Kühn, were evaluated under natural epiphytotic conditions during the Kharif seasons of 2022 and 2023. The initiation, progression, and maximum cumulative Percent Disease Index (PDI) of the disease were substantially influenced by the crop establishment schedule (transplanting date) and the synchronization of susceptible plant growth phases with conductive meteorological regimes (Table 1, Table 3).

In the 2022 crop season, the earliest disease onset occurred in the early-transplanted crop during the 33rd Standard Meteorological Week (SMW) (13–19 August) at the maximum tillering stage, with an initial PDI of 0.5%. The epidemic progressed rapidly and steadily in this treatment, reaching cumulative PDI values of 10.5% in the 38th SMW and 23.3% in the 41st SMW, before culminating in a maximum cumulative severity of 33.8% in the 43rd SMW (22–28 October) at crop physiological maturity. In contrast, disease initiation in the mid-sown crop was delayed until the 37th SMW (10–16 September), coinciding with its maximum tillering phase, with an initial severity of 0.5%. Disease development in the mid-sown crop was characterized by a relatively moderate rate of progression, reaching 9.4% in the 43rd SMW and achieving a final cumulative severity of 26.6% in the 48th SMW (26 November–2 December). For the late-sown crop, disease onset was further delayed to the 40th SMW (1–7 October) with an initial PDI of 1.1%. However, once initiated, the late-sown crop experienced a rapid disease progression during November, with the PDI increasing from 9.4% in the 43rd SMW to a maximum cumulative severity of 31.1% in the 48th SMW.

During the 2023 crop season, the epidemiological patterns of sheath blight progression closely mirrored those of the preceding year, although with slightly higher overall epidemic intensities. In the early-transplanted plots, disease onset was registered in the 33rd SMW (0.5% PDI), followed by a sharp and continuous progression that reached 13.8% in the 38th SMW, 26.6% in the 41st SMW, and a maximum cumulative severity of 36.6% in the 43rd SMW. In the mid-sown crop, the initial symptoms were observed during the 37th SMW (0.5% PDI), and the disease slowly progressed to a final severity of 28.3% in the 48th SMW. The late-sown crop exhibited disease initiation in the 40th SMW (1.6% PDI), which then increased rapidly through November (15.5% in the 44th SMW and 28.8% in the 47th SMW) to culminate in a maximum PDI of 33.3% in the 48th SMW. Across both years, the early transplanting window consistently experienced the highest disease severity (33.8% and 36.6%), whereas the mid-sowing window resulted in the lowest epidemic severity (26.6% and 28.3%), indicating that crop establishment schedules can be optimized to escape peak disease pressure under central Indian conditions.

Epidemiological Characterization of Host-Pathogen Transition Phases

The development of rice sheath blight occurs through two distinct epidemiological phases: a soil-borne primary infection phase (governed by the saprozone inoculum) and a canopy-borne secondary horizontal and vertical spread phase (governed by runner hyphae within the microclimatic pathozone). In the early-sown crop during both years, primary soil-borne inoculum of Rhizoctonia solani initiated basal lesions (Score 1) on the lower sheaths during the 33rd, 34th, and 35th SMWs. Weekly spatial assessments of tagged plants revealed that the number of infected plants expressing primary lesions at the stem base (Score 1) rose from 1 to 6 plants (out of 20 observed) in 2022, and from 2 to 13 plants in 2023. By the 36th SMW, the pathogen transitioned to its secondary canopy-borne phase. Runner hyphae (mycelial strands) emerged from the primary mother lesions at the base of the stem, forming penetration structures and establishing daughter lesions higher up the canopy. Symptoms progressed from typical water-soaked, green-grey, oval-to-elliptical lesions on the lower leaf sheaths (Score 3) to extensive infections spreading to the upper plant parts and mid-canopy leaf sheaths (Score 5). In the early-sown crop, highly conductive weather during the 42nd and 43rd SMWs facilitated severe disease progression, with plants expressing high-grade lesions (Score 7, indicating infection of upper sheaths and flag leaves) increasing to 3 and 1 plants in 2022 and 2023, respectively.

For the mid-sown crop, plants remained entirely healthy (Score 0) during the seedling and early vegetative phases from the 33rd to 36th SMW. The disease initiated exclusively when the crop reached its maximum tillering stage, coinciding with the 37th to 39th SMW (2022) and 37th to 40th SMW (2023). Basal lesion initiation (Score 1) occurred on 1 to 3 tagged plants in 2022 and 1 to 7 plants in 2023. The subsequent rate of secondary canopy spread was slow, with only 1 to 2 plants reaching Score 3 during the 40th to 42nd SMWs. A late-season rise in disease progression was noted during the 45th to 48th SMWs, with the frequency of infected plants showing moderate to high disease scores (Score 5 and 7) reaching 2 (Score 5) and 2 (Score 7) in 2022, and 4 (Score 5) and 3 (Score 7) in 2023.
In the late-sown crop, plants escaped infection for seven consecutive weeks (33rd to 39th SMW) due to their early vegetative growth stage and lack of canopy closure. Disease initiation occurred at maximum tillering during the 40th to 42nd SMW, where primary basal lesions (Score 1) developed rapidly on 2 to 11 plants in 2022 and 3 to 15 plants in 2023. Although the primary incidence of basal lesions was high, the subsequent vertical and horizontal spread in the canopy-borne pathozone was highly restricted during the late season (SMW 44 to 48). A significant reduction was observed in the development of higher-grade infections: in 2022, most plants remain in the lower infection classes (14 plants with Score 3, and only 2 with Score 5 at the 48th SMW); in 2023, the distribution at the 48th SMW was 10 plants at Score 3 and 5 plants at Score 5. Crucially, not a single plant in the late-sown crop expressed high-grade severity (Score 7) in either year. This indicates that while the late-season microclimate allowed primary infection of the dense tillers, it restricted the vertical climbing of runner hyphae to the upper plant parts.

Microclimatic Dynamics and Meteorological Drivers of Infection

The temporal progression of sheath blight was closely linked to the microclimatic conditions within the crop canopy, which were determined by weekly meteorological variations (Table 2, Table 4). During the critical initial and secondary spread phases of the early-sown crop (SMW 33rd to 39th), the prevailing weather conditions were highly conducive to fungal infection and mycelial growth. Morning relative humidity (RH) remained consistently high, ranging from 88.0% to 94.0% in 2022 and 87.4% to 93.3% in 2023, providing the prolonged leaf wetness required for sclerotial germination. This high humidity was coupled with favorable warm thermal regimes, with maximum temperatures of 30.2–32.8°C (2022) and 30.9–33.5°C (2023) and moderate minimum temperatures of 23.0–26.0°C (2022) and 24.1–25.4°C (2023). Frequent and substantial rainfall events, particularly during the 36th and 37th SMWs in both years (86.0 mm and 238.4 mm in 2022; 130.6 mm and 225.8 mm in 2023), further saturated the crop canopy and accelerated horizontal disease spread.
Conversely, from the 40th SMW onwards, the macro- and microclimate shifted toward conditions unfavorable for canopy-borne pathogens. Evening relative humidity declined sharply, dropping to minimum values of 30% to 35% by the 48th SMW. Minimum temperatures plummeted, ranging from 13.6°C to 21.3°C in 2022 and 11.2°C to 23.6°C in 2023. Furthermore, rainfall became extremely scarce or completely absent across both years, with no rainfall recorded from the 40th to 48th SMW except for isolated events (15.2 mm and 48.0 mm in SMW 42 and 47 of 2022; 9.40 mm and 2.50 mm in SMW 40 and 44 of 2023). This reduction in night temperature, absence of rain, and dry evening air deprived the pathogen of the high relative humidity and leaf wetness necessary for runner hyphae survival and host penetration. Consequently, vertical disease progression slowed down drastically during the late season, preventing the late-sown crop from developing severe upper-canopy lesions.

Quantitative Correlation Analysis of Weather Parameters and Disease Severity

To establish quantitative relationships, correlation coefficients (r) between individual weather variables and progressive sheath blight disease severity (PDI) were computed for each transplanting date and year (Table 5). In 2022, maximum temperature exhibited a positive correlation with disease severity across all three transplanting dates, which was statistically significant and became progressively stronger from early ($r = 0.16$) to mid ($r = 0.55$) and late ($r = 0.57$) transplanting. Bright sunshine hours (BSS) demonstrated a highly significant and strong positive correlation with disease severity under early ($r = 0.74$), mid ($r = 0.52$), and late ($r = 0.51$) conditions. Morning relative humidity also showed positive, though weaker, correlations ranging from $r = 0.04$ to $r = 0.20$. In contrast, minimum temperature had an extremely strong, highly significant negative correlation with disease progression ($r = -0.85$ to -0.86) across all crop schedules. Similarly, evening relative humidity exhibited a strong, highly significant negative correlation ($r = -0.71$ to -0.79), while weekly total rainfall was significantly and negatively correlated ($r = -0.31$ to -0.43) with disease severity across all treatments.
In the 2023 season, the correlation dynamics closely corroborated the 2022 findings. Maximum temperature showed a significant positive association with PDI, ranging from $r = 0.21$ in early sowing to $r = 0.52$ and $r = 0.54$ in mid and late sowings. Bright sunshine hours likewise remained significantly and positively correlated across early ($r = 0.48$), mid ($r = 0.45$), and late ($r = 0.43$) transplanting. Morning relative humidity exhibited a significant positive correlation in the early-sown crop ($r = 0.30$), but displayed negative associations in the mid-sown ($r = -0.25$) and late-sown ($r = -0.25$) crops. This negative relationship under late-season conditions reflects the general decline in ambient relative humidity as the season progressed while cumulative disease severity continued its gradual, slow increment. Significant negative correlations were again observed for minimum temperature ($r = -0.65$ to -0.84), evening relative humidity ($r = -0.61$ to -0.75), and weekly rainfall ($r = -0.35$ to -0.50) across all sowing dates.
The apparently paradoxical negative correlations between disease severity and weather factors like rainfall and evening relative humidity are epidemiologically rational. Because disease severity is assessed cumulatively, it continues to increase over time even after rainfall has ceased and humidity has declined. The primary infections are established during the early-season rainfall and high-humidity windows; subsequent disease progression and vertical climb are

driven by canopy-level microclimates and existing internal humidity, which decouples late-stage disease development from late-season external rainfall events.

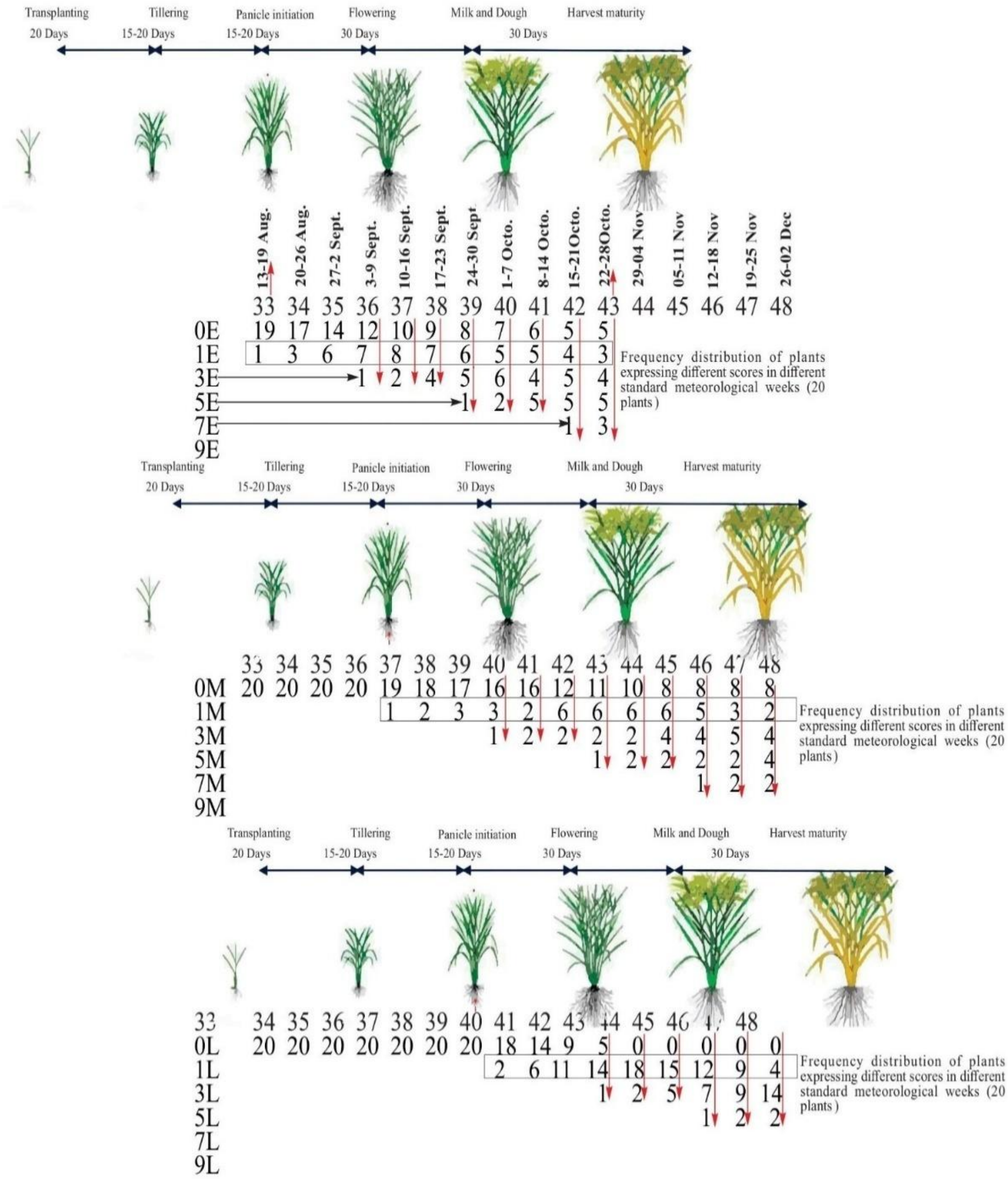

Fig. 1. Sheath blight disease progression in different crop stages

Table 1. Development of sheath blight disease (cumulative increment in PDI) in relation to weather parameters (Season 2022)

Standard Metrological Week	Period of Observation	Early crop	Mid-crop	Late crop
		Cumulative increase in PDI (%)	Cumulative increase in PDI (%)	Cumulative increase in PDI (%)
33	13-19 Aug.	0.5	0	0
34	20-26 Aug.	1.6	0	0
35	27-2 Sept.	3.3	0	0
36	3-9 Sept.	5.5	0	0
37	10-16 Sept.	7.7	0.5	0
38	17-23 Sept.	10.5	1.1	0
39	24-30 Sept.	14.4	1.6	0

40	1-7 Octo.	18.3	3.3	1.1
41	8-14 Octo.	23.3	4.4	3.3
42	15-21Octo.	28.3	6.6	6.1
43	22-28Octo.	33.8	9.4	9.4
44	29-04 Nov	-	12.2	13.3
45	05-11 Nov	-	15.5	16.6
46	12-18 Nov	-	18.8	21.1
47	19-25 Nov	-	23.3	25.5
48	26-02 Dec	-	26.6	31.1

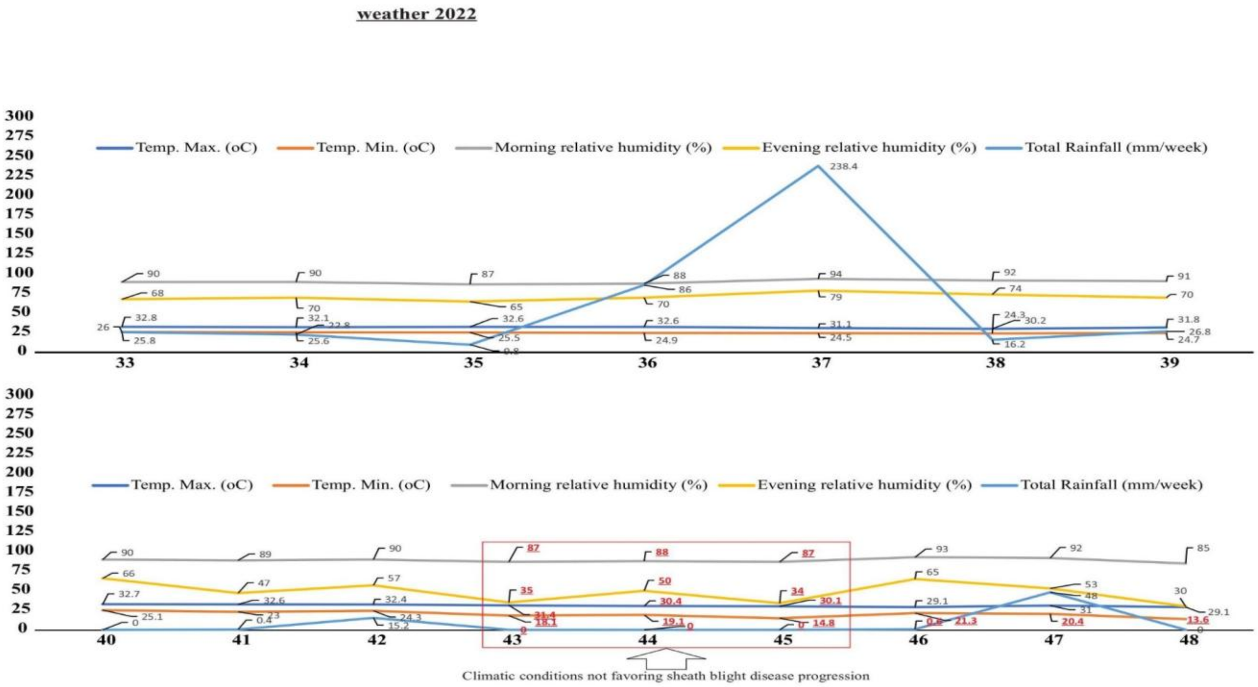

Fig. 2. Weekly meteorological data during crop growth period of kharif 2022

Table 2. Weekly meteorological data during crop growth period of kharif 2022

Std. Metrological Week	Period of Observation	Temp. Max. (ºC)	Temp. Min. (ºC)	Morning relative humidity (%)	Evening relative humidity (%)	Total Rainfall (mm/week)
33	13-19 Aug.	32.8	26.0	90	68	25.8
34	20-26 Aug.	32.1	25.6	90	70	22.8
35	27-2 Sept.	32.6	25.5	87	65	9.8
36	3-9 Sept.	32.6	24.9	88	70	86.0
37	10-16 Sept.	31.1	24.5	94	79	238.4
38	17-23 Sept.	30.2	24.3	92	74	16.2
39	24-30 Sept.	31.8	24.7	91	70	26.8
40	1-7 Octo.	32.7	25.1	90	66	0.0
41	8-14 Octo.	32.6	23.0	89	47	0.4
42	15-21Octo.	32.4	24.3	90	57	15.2
43	22-28Octo.	31.4	18.1	87	35	0.0
44	29-04 Nov	30.4	19.1	88	50	0.0
45	05-11 Nov	30.1	14.8	87	34	0.0
46	12-18 Nov	29.1	21.3	93	65	0.6
47	19-25 Nov	31.0	20.4	92	53	48.0
48	26-02 Dec	29.1	13.6	85	30	0.0

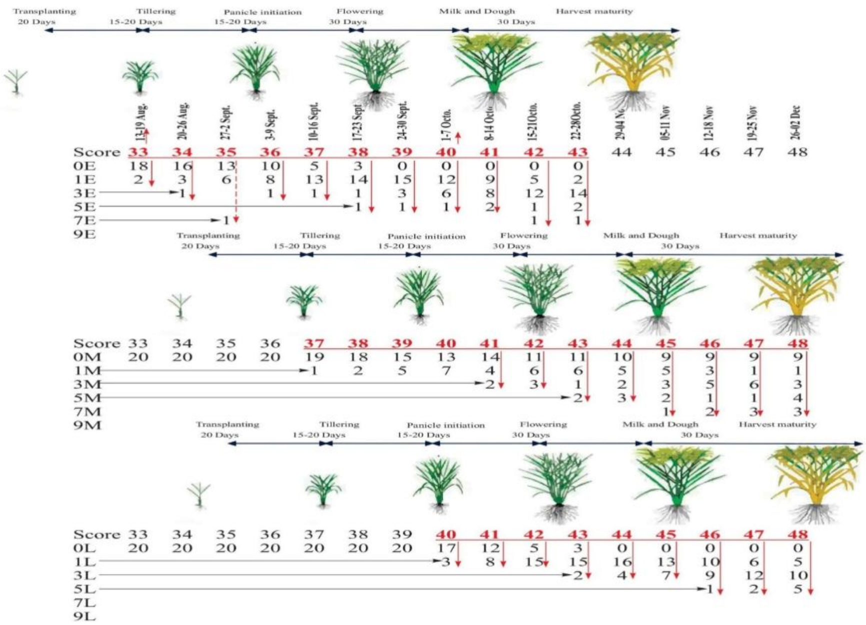

Fig. 3. Sheath blight disease progression in different crop stages

Table 3. Development of sheath blight disease (cumulative increment in PDI) in relation to weather parameters (Season 2023)

Standard Metrologic al Week	Period of Observati on	Early crop	Mid-crop	Late crop
		Cumulative increase in PDI (%)	Cumulative increase in PDI (%)	Cumulative increase in PDI (%)
33	13-19 Aug.	0.5	0	0
34	20-26 Aug.	1.6	0	0
35	27-2 Sept.	3.8	0	0
36	3-9 Sept.	6.6	0	0
37	10-16 Sept.	10.5	0.5	0
38	17-23 Sept.	13.8	1.1	0
39	24-30 Sept.	17.7	2.7	0
40	1-7 Octo.	22.2	3.8	1.6
41	8-14 Octo.	26.6	5.5	4.4
42	15-21Octo.	32.2	8.3	8.3
43	22-28Octo.	36.6	10.5	11.6
44	29-04 Nov	-	14.4	15.5
45	05-11 Nov	-	17.2	18.8
46	12-18 Nov	-	20.5	23.3
47	19-25 Nov	-	25.0	28.8
48	26-02 Dec	-	28.3	33.3

Table4. Weekly meteorological data during crop growth period of kharif (2023)

Std. Metrolo gical Week	Period of Observation	Temp. Max. (ºC)	Temp. Min. (ºC)	Morning relative humidity (%)	Evening relative humidity (%)	Total Rainfall (mm/week)

33	13-19 Aug.	33.1	24.65	87.42	65.42	184.4
34	20-26 Aug.	31.1	25.4	89.85	70.28	8.20
35	27-2 Sept.	33.5	25.4	88.00	59.00	15.00
36	3-9 Sept.	30.87	24.14	91.14	77.00	130.6
37	10-16 Sept.	31.1	25.24	90.71	73.00	225.8
38	17-23 Sept.	31.35	25.02	90.71	72.85	101
39	24-30 Sept.	31.57	24.92	93.28	69.71	22.2
40	1-7 Octo.	32.64	23.6	82.71	55.42	9.40
41	8-14 Octo.	34.4	23.32	92.28	45.42	0.00
42	15-21Octo.	32.94	21.35	88.00	44.00	0.00
43	22-28Octo.	30.67	17.02	89.14	33.71	0.00
44	29-04 Nov	31.11	18.96	89.29	52.57	2.50
45	05-11 Nov	31.83	17.34	89.71	34.57	0.0
46	12-18 Nov	31.03	16.97	86.43	45.00	0.0
47	19-25 Nov	30.64	17.43	84	42	0.0
48	26-02 Dec	29.5	11.2	87	33	0.0

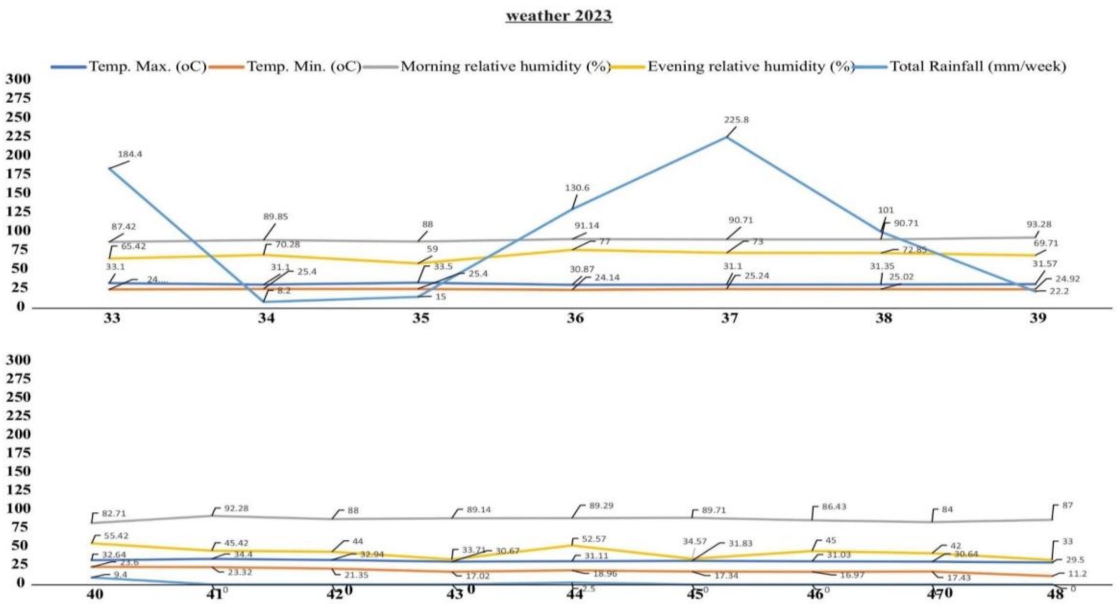

Fig. 4.Weekly meteorological data during crop growth period of kharif (2023)

Table 5. Year wise correlation coefficient between weather parameters and sheath blight disease severity over two years kharif season (2022-2023)

Period of Observation	**Temp. Max. (°C)**		**Temp. Min. (°C)**		**Morning relative humidity (%)**		**Evening relative humidity (%)**		**Bright Sunshine Hrs/day**		**Total Rainfall (mm/week)**	
Years	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
Early sowing	0.16	0.21	-0.85	-0.65	0.20	0.30	-0.79	-0.61	0.74	0.48	-0.31	-0.35
Mid sowing	0.55	0.52	-0.86	-0.84	0.06	-0.25	-0.73	-0.75	0.52	0.45	-0.41	-0.50

Late sowing	0.57	0.54	-0.85	-0.84	0.04	-0.25	-0.71	-0.73	0.51	0.43	-0.43	-0.46

DISCUSSION

Influence of Transplanting Dates on Sheath Blight Initiation and Epidemic Dynamics

Optimizing crop establishment schedules is a highly effective cultural strategy to alter the microclimatic environment and decouple susceptible crop growth phases from highly conductive meteorological regimes. In this study, the crop transplanting date exerted a profound influence on the initiation, progression rate, and final cumulative severity of rice sheath blight, caused by Rhizoctonia solani Kühn, across both the 2022 and 2023 Kharif seasons.

In the early-transplanted crop during 2022, disease onset was registered exceptionally early, starting in the 33rd Standard Meteorological Week (SMW) (13–19 August) during the maximum tillering stage with a baseline Percent Disease Index (PDI) of 0.5%. Supported by highly conductive weather, the disease progressed rapidly, recording a cumulative PDI of 10.5% in the 38th SMW, 23.3% in the 41st SMW, and culminating in a maximum cumulative severity of 33.8% in the 43rd SMW (22–28 October) as the crop reached physiological maturity. The 2023 season closely mirrored this pattern but with slightly higher overall epidemic intensities, initiating in the 33rd SMW (0.5% PDI), expanding to 13.8% in the 38th SMW, 26.6% in the 41st SMW, and reaching a maximum cumulative PDI of 36.6% in the 43rd SMW. This rapid and severe disease progression under early sowing demonstrates that early crop establishment aligns critical vegetative and reproductive phases with the peak of seasonal environmental conduciveness, fostering severe epidemics.

Conversely, the mid-transplanted crop consistently experienced the lowest final cumulative disease severity in both years, registering 26.6% in 2022 and 28.3% in 2023. In this treatment, the initial symptoms were delayed until the 37th SMW (10–16 September), starting at 0.5% PDI. The subsequent progression remained highly moderate, showing a gradual cumulative rise to only 9.4% (2022) and 10.5% (2023) by the 43rd SMW, before culminating at the 48th SMW. This delayed onset and slower progress indicates that mid-sown crops successfully bypass the extreme early-season pathogen pressure.

Interestingly, the late-transplanted crop exhibited a unique epidemiological behavior. Disease initiation was delayed until the 40th SMW (1–7 October), starting with an initial PDI of 1.1% in 2022 and 1.6% in 2023. However, once established, the late-sown crop experienced a rapid late-season acceleration during November, with the PDI climbing sharply from 9.4% (2022) and 11.6% (2023) in the 43rd SMW to a maximum cumulative severity of 31.1% (2022) and 33.3% (2023) in the 48th SMW. This late-season surge is linked to late-stage canopy closure and dense tillering, which trap moisture and sustain disease progression even as the external macroclimate dries out.

These findings align with the work of Biswasiet al. (2011), who demonstrated that meteorological variations driven by transplanting schedules govern the initiation and progress of sheath blight epidemics. They are also supported by Srinivasacharyet al. (2013) and Khoshkdamanet al. (2021), who noted that altering planting dates alters disease onset and progression by shifting the crop's physiological state relative to seasonal weather dynamics.

Host-Pathogen Transition Phases: Primary Soil-Borne Infection vs. Secondary Canopy-Borne Spread

Epidemiologically, rice sheath blight progresses through two distinct biophysical phases: an initial soil-borne primary infection phase (restricted to the saprozone inoculum near the soil-water interface) and a subsequent canopy-borne secondary horizontal and vertical spread phase (driven by runner hyphae climbing the foliage within the microclimatic pathozone).

The Primary Infection Phase (Saprozone): During both crop seasons, the soil-borne primary inoculum (sclerotia and vegetative hyphae in the soil) initiated basal lesions (Score 1) on the lower leaf sheaths of the early-sown crop during the 33rd, 34th, and 35th SMWs. Weekly spatial monitoring of tagged plants revealed a rapid increase in disease incidence at the base, with the number of plants expressing basal Score 1 lesions rising from 1 to 6 plants (out of 20 observed) in 2022, and from 2 to 13 plants in 2023. This phase is highly dependent on early-season moisture which triggers sclerotial germination.

The Secondary Spread Phase (Pathozone): By the 36th SMW, the pathogen transitioned to its secondary canopy-borne phase. Runner hyphae (mycelial strands) emerged from the primary basal lesions, forming complex penetration structures (infection cushions) and establishing new daughter lesions higher up the canopy. Symptoms progressed from water-soaked, green-grey, oval-to-elliptical lesions on lower sheaths (Score 3) to expansive lesions covering mid-canopy sheaths (Score 5). In the early crop, highly conductive weather in October facilitated severe vertical climbing, with plants reaching Score 7 (infection of upper sheaths and flag leaves) increasing to 3 plants in 2022 and 1 plant in 2023.

In the mid-sown crop, plants remained completely healthy (Score 0) during the seedling and early vegetative stages from the 33rd to 36th SMW due to the lack of canopy closure and younger tissue age. Primary basal lesions (Score 1) initiated exclusively at maximum tillering, which coincided with the 37th to 39th SMW in 2022 (1 to 3 plants) and 37th to 40th SMW in 2023 (1 to 7 plants). The subsequent canopy-borne spread was highly restricted, with only 1 to 2 plants reaching Score 3 during the 40th to 42nd SMWs. A late-season surge in disease progression was noted during the 45th to 48th SMWs, with some plants eventually climbing to higher infection grades (Score 5 and 7).

In the late-sown crop, the plants successfully escaped infection for seven consecutive weeks (33rd to 39th SMW) due to their early vegetative stages and lack of canopy closure, representing a classical disease escape mechanism. Disease initiation occurred rapidly at maximum tillering during the 40th to 42nd SMWs, with primary basal lesions (Score 1) developing on 2 to 11 plants (2022) and 3 to 15 plants (2023). However, because of unfavorable late-season weather, the subsequent vertical climb of runner hyphae was highly restricted. At the 48th SMW, the vast majority of late-sown plants remained trapped in the lower infection classes (14 plants at Score 3 and 2 at Score 5 in 2022; 10 plants at Score 3 and 5 at Score 5 in 2023), and not a single plant reached Score 7 in either year.

These transition dynamics are strongly supported by the pathological and histopathological findings of Roy et al. (2025), who showed that the density of fungal hyphae and the formation of infection cushions are heavily restricted under unfavorable host or environmental conditions. Furthermore, Wu et al. (2013) demonstrated through stepwise multiple regression that canopy contact frequency is the most consistent parameter driving secondary sheath blight epidemics, explaining why late-sown and mid-sown crops escape early-season secondary vertical climbing before their canopies close. Additionally, the detached tiller and inoculum studies by Lore et al. (2021) and Hunjanet al. (2022) corroborate that primary lesion initiation is governed by inoculum efficiency, whereas subsequent vertical climbing represents an active, weather-dependent physiological and microclimatic process.

Microclimatic Conduciveness and Meteorological Regimes Governing Pathogen Development

The temporal progression and vertical stratification of sheath blight lesions were tightly regulated by the ambient microclimate within the crop canopy, which fluctuated based on weekly meteorological conditions.

During the critical initiation and secondary spread phases of the early-sown crop (SMWs 33rd to 39th), the microclimate was exceptionally favorable for Rhizoctonia solani growth. Morning relative humidity (RH) remained consistently high, ranging from 88.0% to 94.0% in 2022 and 87.4% to 93.3% in 2023, which provided the prolonged leaf wetness required for sclerotial germination and hyphal survival. This high humidity was coupled with optimal warm thermal regimes, featuring maximum temperatures of 30.2–32.8°C (2022) and 30.9–33.5°C (2023) and minimum temperatures of 23.0–26.0°C (2022) and 24.1–25.4°C (2023). Furthermore, frequent and heavy rainfall events, particularly during the 36th and 37th SMWs in both years (86.0 mm and 238.4 mm in 2022; 130.6 mm and 225.8 mm in 2023), thoroughly saturated the crop canopy and washed down sclerotia, accelerating horizontal disease spread.

In stark contrast, from the 40th SMW onwards, the microclimatic conditions shifted rapidly toward regimes hostile to canopy-borne pathogens. Evening relative humidity declined sharply, plummeting to minimum values of 30% to 35% by the 48th SMW. Minimum temperatures plummeted, ranging from 13.6°C to 21.3°C in 2022 and 11.2°C to 23.6°C in 2023. In addition, rainfall became extremely scarce or completely absent across both seasons, with no rain recorded from the 40th to 48th SMWs except for minor isolated events. This combination of dry evening air, low night temperatures, and lack of precipitation deprived the pathogen of the high relative humidity and leaf wetness required for runner hyphae to remain turgid and penetrate host tissues. Consequently, vertical disease progression slowed down drastically during the late season, explaining why the late-sown crop, despite having high primary basal incidence, was completely unable to develop severe, upper-canopy lesions (Score 7).

These temperature and humidity thresholds are in perfect agreement with Biswasiet al. (2011), who reported that a maximum temperature around 34°C, a minimum temperature around 26°C, and morning relative humidity exceeding 90% are the optimal drivers for the spread of sheath blight after its establishment. These findings also align with broader weather-driven disease models, such as EPIRICE and BGRcast, which rely heavily on relative humidity, leaf wetness, and temperature grids to simulate infection risk. The overriding effect of these weather fluctuations over other agronomic factors in rice fields is also well documented by Chiu et al. (2022), who demonstrated that weather dynamics frequently override nutrient management systems in dictating fungal disease incidence.

Quantitative Correlation Dynamics: Thermal Regimes, Sunshine, and Paradoxical Moisture Relationships

To establish a mathematically rigorous basis for these relationships, correlation coefficients (r) were calculated between individual weather parameters and progressive disease severity (PDI) across all sowing dates. The statistical correlations reveal a highly structured response to environmental variables:

Maximum Temperature: Exhibited a statistically significant, positive correlation across all treatments, which became progressively stronger from early (r = 0.16) in 2022; (0.21) in 2023) to mid (r = 0.55) in 2022; (0.52) in 2023) and late (r = 0.57) in 2022; (0.54) in 2023) sowing dates. This reflects the positive influence of warm daytime temperatures on fungal metabolic activity.

Bright Sunshine Hours (BSS): Demonstrated a highly significant, strong positive correlation with disease progression across early (r = 0.74) in 2022; (0.48) in 2023), mid (r = 0.52) in 2022; (0.45) in 2023), and late (r = 0.51) in 2022; (0.43) in 2023) conditions.

Morning Relative Humidity: Showed a positive correlation in 2022 (r = 0.04) to (0.20) and early 2023 (r = 0.30), but turned negatively associated in mid (r = -0.25) and late (r = -0.25) 2023 crops.

Minimum Temperature, Evening Relative Humidity, and Rainfall: Consistently exhibited strong, highly significant negative correlations across all crop schedules. Minimum temperature correlations ranged from (r = -0.85) to (-0.86) in 2022 and (r = -0.65) to (-0.84) in 2023. Evening RH correlations ranged from (r = -0.71) to (-0.79) (2022) and (r = -0.61) to (-0.75) (2023). Total rainfall showed negative correlations of (r = -0.31) to (-0.43) (2022) and (r = -0.35) to (-0.50) (2023).

Resolving the Moisture and Temperature Paradox

The highly significant negative correlations between cumulative disease severity and moisture variables (rainfall and evening relative humidity) are epidemiologically rational and represent a common phenomenon in cumulative disease indexing. Because sheath blight severity is assessed as a cumulative increment over the crop cycle, the PDI value mathematically continues to rise or stay constant over time, even after seasonal rainfall has completely ceased and evening air has dried out.

The primary infections are established during the early-season rainfall and high-humidity windows. Once these lesions are established, the subsequent vertical progression is sustained by the dense crop canopy's microclimate and localized humidity, effectively decoupling late-season disease progress from external macroclimatic rainfall events. Similarly, the negative morning RH correlations during the mid and late 2023 seasons (r = -0.25) represent the general seasonal decline of ambient relative humidity as autumn progressed, while the cumulative disease index maintained its slow, gradual increment.

This statistical behavior aligns with cumulative epidemiological modeling described by Mousanejadet al. (2010) and Mukherjee et al. (2010), who noted that temporal lags between weather events and cumulative disease assessments often result in negative correlation coefficients for late-season weather variables. It also highlights why daily risk models, such as the EPIRICE daily model, are highly sensitive to relative humidity inputs when capturing non-cumulative daily infection risk.

Epidemiological Implications and Strategic Crop Management for Sheath Blight Escape

The findings of this study have direct, practical implications for the development of integrated pest management (IPM) systems under central Indian conditions:

Optimization of Crop Scheduling (Disease Escape): The mid-sowing (transplanting) window represents the highly recommended crop establishment schedule, consistently yielding the lowest disease severity (26.6% in 2022 and 28.3% in 2023). Sowing too early subjects the young canopy to the highly conductive high-rainfall, high-humidity regime of August and September, leading to severe vertical climbing. Sowing too late, while allowing the upper plant parts to escape infection, leads to a rapid late-season build-up of basal lesions due to dense vegetative mass during November.

Precision Fungicide and Seed Treatments: Since maximum tillering represents the critical susceptibility window where primary soil-borne infections transition into destructive secondary canopy-borne spread, chemical interventions should be timed precisely to this phase. If maximum tillering is predicted to coincide with high-rainfall windows, proactive protective measures (such as the chemical fungicides Tebuconazole or Difenoconazole evaluated by Thapa et al., 2026, or seed priming/treatments as evaluated by Dhillon et al., 2025) should be prioritized.

Integration with Tolerant Cultivars: These cultural schedules should be coupled with host physiological resistance. Utilizing quantitative resistance sources such as Tetep—which has been extensively validated to restrict sheath blight severity, relative lesion height (RLH), and vertical sheath colonization (VSC)—in combination with a mid-transplanting window, will provide a highly robust, multi-layered defense against Rhizoctonia solani epidemics.

This dual strategy of aligning weather-driven epidemiological forecasting (such as warning models described by Kang et al., 2010 and Shin et al., 2025) with optimized cultural escape and genetic tolerance, offers a highly sustainable pathway for crop protection and food security in changing climates.

CONCLUSION

The results from this multi-season epidemiological study (consecutive Kharif seasons 2022 and 2023) confirm that transplanting dates are an important cultural practice to modify the microclimate of the crop and manage rice sheath blight (Rhizoctonia solani Kühn). The vulnerable stages of the crops coincided with increased environmental conduciveness during the first transplanting of the 33rd Standard Meteorological Week (SMW), resulting in early disease occurrence and high maximum percent disease index (PDI) values of 33.8% and 36.6% in 2022 and 2023, respectively. On the other hand, mid-season transplanting (37th SMW) acted as a good cultural escape window consistently recording the lowest final cumulative disease severity in both years (26.6% and 28.3%, respectively). Late (40th SMW) transplanting resulted in disease onset being delayed, but in November disease development was rapid following onset, reaching PDI of up to 33.3%. It was found that the disease had a soil-borne primary infection phase in the saprozone, close to the water line, and a secondary infection phase in the canopy linked to the saprotrophic (climbing runner hyphae) phase of the disease in the pathozone. August and September brought high relative humidity (87.4 – 94.0%), warm temperatures (30.2 – 33.5°C) and a high frequency of heavy rainfall events that resulted in high vertical climbing in early sowed crops. In contrast, the few plants that were seeded in late spring experienced low relative humidity (30-35%), cool minimum temperatures (11.2-13.6°C), and dry late-season weather (after the 40th SMW) that helped to retard secondary vertical climbing, and thus prevented late-sown plants from becoming infected with high grades (Score 7). Progressive disease severity was positively correlated with maximum temperature and bright sunshine hours but strongly and significantly negatively correlated with minimum temperature, evening relative humidity and rainfall. This negative relationship is an epidemiological paradox of cumulative disease indexing because cumulative values mathematically continue to increase late in the season when monsoonal weather is dry and microclimatic factors continue to keep the disease going. These findings point towards an integrated pest management (IPM) system for controlling sheath blight in rice cultivation in central India by using selective chemical or biological treatment at the critical time of susceptible phase of the crop, when primary infection is transitioning to secondary vertical infection, along with mid-season transplanting as a cultural escape.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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