



RESEARCH ARTICLE

Epidemiology and prevalence of rice sheath rot disease under foothill conditions of Nagaland

Fivalyne War¹, Narola Pongener^{1*}, Hijam Meronbala Devi¹, Bireswar Sinha¹, Waluniba² & Damitre Lytan²

¹Department of Plant Pathology, School of Agricultural Sciences, Medziphema Campus, Nagaland University, Medziphema 797 106, Nagaland, India

²Department of Entomology, School of Agricultural Sciences, Medziphema Campus, Nagaland University, Medziphema 797 106, Nagaland, India

*Correspondence email - naropongen@nagalanduniversity.ac.in

Received: 05 March 2026; Accepted: 03 June 2026; Available online: Version 1.0: 18 August 2026

Cite this article: Fivalyne W, Narola P, Hijam MD, Bireswar S, Waluniba, Damitre L. Epidemiology and prevalence of rice sheath rot disease under foothill conditions of Nagaland. Plant Science Today. 2026; 13(sp6): 1-10. <https://doi.org/10.14719/pst.14413>

Abstract

Despite being a major staple food crop, rice (*Oryza sativa* L.) of the Gramineae family is plagued by several diseases, one of which is sheath rot (*Sarocladium oryzae* W.) causing significant yield and economic losses. The study was conducted in Nagaland during kharif 2022 to screen 27 rice genotypes along with one resistant check variety against rice sheath rot disease under natural field conditions. Disease identification was done based on field symptom expression, followed by pathogen isolation and microscopic examination of morphological characteristics. Results of screening revealed that among the tested genotypes, only three were immune, eight resistant, ten moderately resistant and six moderately susceptible to sheath rot disease. The highest mean disease incidence (44.17 %), disease severity (30.86 %) and area under disease progress curve (AUDPC) values (371.57) were recorded in genotype *Apuapa*, whereas the lowest in *Thangmo*, *Thupfu Lha* and *Chali* as no disease symptoms were observed. In addition to factors like susceptible cultivars, meteorological conditions also significantly contributed to disease development and spread. So, for epidemiological study, the correlation analysis revealed a significant positive correlation between sheath rot severity and maximum relative humidity while temperature and minimum relative humidity showed negative correlations. Simple regression analysis showed that among the weather parameters, maximum relative humidity with R^2 value of 0.878 influenced sheath rot severity of up to 87 %. These findings may support future breeding programmes focused on developing resistant cultivars, as well as improving crop loss prediction for sustainable disease management and yield protection.

Keywords: disease severity; epidemiology; Nagaland; rice genotypes; screening; sheath rot

Introduction

Rice (*Oryza sativa* L.) belonging to the Gramineae family, is a primary cereal crop that serves as the daily bread for more than 50 % of the world's inhabitants playing a vital role in global food security (1). As an excellent source of carbohydrates, energy and proteins, it provides nearly 21 % of dietary energy and 15 % of protein intake (2). Thus, it serves as a source of nutrition for people ever since civilisation first emerged and as the central core of people's culture and lifestyles (1).

According to the United States Department of Agriculture, global rice production during 2024/2025 was estimated at 535.8 million tons (Mt) (3). India is the world's second-largest rice producer, cultivating rice across nearly 44 million hectares (Mha) under diverse agro-climatic conditions. Rice occupies about 14 % of the country's geographical area and nearly one-fourth of its cultivable land (4). India also ranks second globally in rice consumption after China, with a production of over 150.18 Mt during 2024–25 (5). In Nagaland, where agriculture supports nearly 70 % of the population either directly or indirectly, rice is the principal cereal crop, with a production of about 0.178 Mt in 2023 (6).

Despite being a major staple food, rice is plagued by a number of diseases, one of which is sheath rot disease

(*Sarocladium oryzae* W.) which can be quite severe and result in significant crop productivity as well as economic losses (7). Sheath rot pathogen mostly affects the economic component of the rice plant, namely the boot leaf sheath encapsulating developing panicles and slows or inhibits panicle emergence, resulting in discolored, chaffy and infertile grains; thus, greatly lower grain output and quality (8). Although the disease has emerged as a serious threat capable of causing yield losses ranging from 20–85 %, yet identification of resistant sources remain limited and immune genotypes are rarely reported (9). Previous studies have largely focused on disease occurrence, pathogen variability and molecular characterisation, while systematic field screening of diverse rice germplasm under natural field conditions has remained insufficient. Moreover, the pathogen also exhibits considerable morphological, pathogenic, toxigenic and genetic variability across rice-growing regions, resulting in unstable and location-specific resistance, thereby necessitating the need for continuous screening of rice cultivars for identification of durable resistance sources (10). In addition, disease development, severity and transmission are significantly influenced by environmental factors such as humidity, temperature, rainfall and sunlight (11), particularly when favourable conditions coincide with susceptible growth stage of the host plant (12), suggesting that cultivar responses may vary under different

agro-climatic conditions (9). Considering the economic significance of sheath rot impacting rice plants at practically all phases of development, screening rice genotypes for resistance and examining the relationship between disease severity and weather parameters are essential so as to identify promising resistant genotypes. This can be useful in future breeding programmes to generate resistant cultivars and also for understanding host-pathogen interactions, predicting crop losses, developing sustainable disease management strategies and yield protection. Therefore, the present study aimed to evaluate rice genotypes for resistance against sheath rot under natural field conditions and to assess the correlation between sheath rot severity and meteorological variables.

Materials and Methods

Location

The study was carried out at the experimental field of Department of Genetics and Plant Breeding and laboratory of Department of Plant Pathology, School of Agricultural Sciences, Nagaland University, Medziphema, in the Chumoukedima district, which is located at an altitude of 310 m above mean sea level and geographically located at 25°45'43" N latitude and 93°53'04" E longitude. Medziphema lies in the sub-humid tropical region with high humidity and moderate temperature (12–32 °C), having moderate to high rainfall (1800–2000 mm) and relative humidity of 70–80 %.

Soil condition

The soil condition of the experimental site was well drained and sandy loam in texture with good water holding capacity. The soil was acidic in nature having a pH of 4.8, which was determined by potentiometric method in 1:2.5 ratio of soil-water suspension using pH meter (13).

Field experiments

The experiment was conducted during the kharif season of 2022 following direct-seeded rice method. During the study, 27 rice genotypes along with 1 resistant check (RCM-9) were collected from State Agricultural Research Station (SARS), Mokokchung, Nagaland. The field was prepared by two ploughings which was followed by a rotovator to bring the soil to a fine tilth. Sowing was done on 3rd June 2022 by line sowing method, with grains directly sown at a spacing of 20 cm between rows in plots measuring 2 m × 1 m. The experiment was laid out in a randomised block design (RBD) with three replications.

Meteorological data collection

Phenological and meteorological data for epidemiological studies was collected from ICAR RC- NEH Region, Nagaland Centre, Jhamapani, Medziphema, Dimapur, Nagaland. The weather parameters were selected as these meteorological variables represented the major environmental conditions to influence sheath rot incidence and severity under natural epiphytotic conditions

Table 1. Meteorological data during the present study

Dates of observation	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Number of rainy days
	T _{max} (°C)	T _{min} (°C)	RH _{max} (%)	RH _{min} (%)		
12 th Sept 2022	34.30	22.90	90.00	82.00	19.20	1.00
27 th Sept 2022	31.90	23.20	93.00	65.00	0.00	0.00
12 th Oct 2022	27.80	21.10	93.00	66.00	2.60	1.00
27 th Oct 2022	28.40	17.80	96.00	60.00	0.00	0.00

RH_{max}: maximum relative humidity; RH_{min}: minimum relative humidity; T_{min}: minimum temperature (°C); T_{max}: maximum temperature (°C).

(Table 1).

Disease assessment

Randomly selected 10 plants were tagged from each plot for disease scoring. Starting with the appearance of the disease symptoms under natural field conditions (Fig. 1), the tagged plants within each plot were visually evaluated for percent foliar infection (severity). A total of 4 scorings was done at 15 days interval from 12th September to 27th October 2022. The visual rating and severity of each disease per sampling plot was recorded based on a disease rating scale of zero to nine (0–9) given by International Rice Research Institute (IRRI) (14) (Fig. 2, Table 2).

Disease incidence

It was assessed by counting the number of infected plants and dividing by the total number of plants assessed using the following formula (15).

$$DI (\%) = \frac{\text{Number of infected plants}}{\text{Total number of plants assessed}} \times 100$$

where: DI = disease incidence

Disease severity

Disease severity measured the level of the quantity of the disease affecting rice plants within a population. Percent disease index (PDI) was calculated using the following formula (16):

$$PDI (\%) = \frac{\text{Sum of individual numerical ratings}}{\text{Number of plants assessed} \times \text{Maximum disease rating on scale}} \times 100$$

where: PDI = percent disease index



Fig. 1. Disease symptoms of rice sheath rot under natural field conditions.

Table 2. Disease rating scale for screening against sheath rot (*Sarocladium oryzae*) disease

Scale	Description	Incidence: % diseased tillers	Host response
0	No lesion/spots on flag leaf sheath	No symptom observed	Immune
1	Spots visible on the tillers upon careful examination	Less than 1 %	Resistant
3	Spots visible on the tillers upon careful examinations	1–5 %	Moderately resistant
5	Spots easily available on the tillers	6–25 %	Moderately susceptible
7	Spots present almost all the tillers	26–50 %	Susceptible
9	Spots very common on whole tiller parts	51–100 %	Highly susceptible

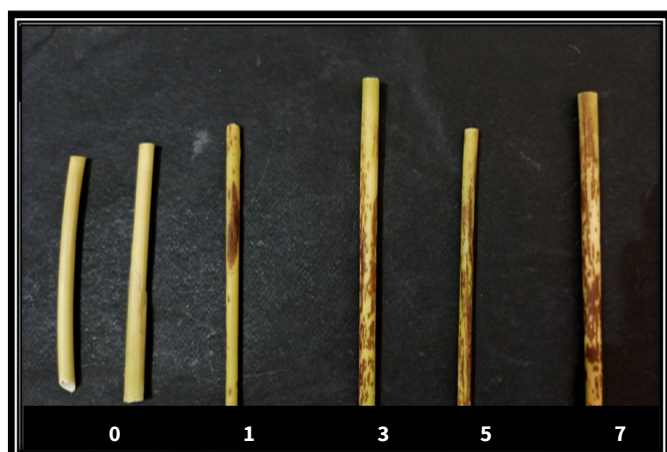


Fig. 2. Sheath rot disease rating recorded based on a scale of 0–7 given by IRRI, 2013.

Area under disease progress curve

Area under disease progress curve gave a quantitative measure of disease intensity and increment, which summarised the progress of disease severity along a time period and was calculated using the following formula (17).

$$AUDPC = \sum_{i=1}^{n-1} (Y_{i+1} + Y_i) 0.5 (T_{i+1} - T_i)$$

where: Y_i = disease severity on the i^{th} date; T_i = date on which the disease was scored; n = numbers of dates on which disease was scored.

Statistical analysis

Disease assessment data was subjected to analysis of variance (ANOVA) for statistical inference using Microsoft Office Excel 2010 following the statistical method for RBD with 5 % and 1 % level of significance (18). Correlation coefficient (Karl Pearson's coefficient) and simple regression analysis was calculated using the software IBM SPSS version 28 to determine the influence of meteorological parameters on sheath rot disease severity among the different rice genotypes.

Table 3. Reaction of rice genotypes to sheath rot disease during screening

Disease score	Mean PDI %	Host reaction	Number of genotypes	Genotypes
0	0	Immune	3	<i>Thangmo, Thupfu Lha, Chali</i>
1	1–10	Resistant	8	<i>Pfukhi Lha, Goyo Tsuk, Thangmo White, Amusu, Taposen Youli, Manen Red, Kedayishye, Longkhum Tsuk</i>
3	11–25	Moderately resistant	10	<i>Moya Chali, Shyekenyi, Rosho Lha, Ngoni, Chishoghi, Chaheshye, Tsungmiki, Kezie, Sungmangtsuk, Sulijak</i>
5	25–50	Moderately susceptible	6	<i>Tungo, Moyatsuk, Tsushvuri, Yarba, Apuapa, Ongpangtsuk</i>

*Score of check variety (RCM-9): 3 (moderately resistant/moderately susceptible).

Results

Screening and response of rice genotypes against sheath rot disease

Screening of 27 rice genotypes against rice sheath rot disease was conducted from 12th September to 27th October 2022 under natural field setting. After careful inspection, the results revealed that three entries namely *Thangmo*, *Thupfu Lha* and *Chali* were immune to sheath rot disease as per the scale of 0–9 given by IRRI (2013) (Table 3). However, the resistant check RCM-9 scored 3 and was categorised as moderately resistant. The results also revealed that eight genotypes (*Pfukhi Lha*, *Goyo Tsuk*, *Thangmo White*, *Amusu*, *Taposen Youli*, *Manen Red*, *Kedayishye* and *Longkhum Tsuk*) were resistant. Ten rice genotypes (*Moya Chali*, *Shyekenyi*, *Rosho Lha*, *Ngoni*, *Chishoghi*, *Tsungmiki*, *Kezie*, *Sulijak*, *Sungmangtsuk* and *Chaheshye*) were moderately resistant and six genotypes (*Tungo*, *Moya Tsuk*, *Tsushvuri*, *Yarba*, *Apuapa* and *Ongpangtsuk*) were found to be moderately susceptible to rice sheath rot disease. Additionally, Fig. 3 showed that 11 % genotypes were immune, 30 % resistant, 37 % moderately resistant and 22 % moderately susceptible.

Degree of severity of rice sheath rot

Based on the results obtained during the study, the disease incidence and severity varied among the rice genotypes as depicted in Table 4. The highest mean disease incidence was observed in genotype *Apuapa* (44.17 %) followed by *Ongpangtsuk* (43.33 %) and the lowest mean disease incidence was observed in *Thangmo*, *Thupfu Lha* and *Chali* with 0.00 % incidence, followed by *Goyo Tsuk* (5.83 %), *Pfukhi Lha* (7.50 %), *Amusu* (10.83 %) and check variety RCM-9 (10.83 %) as shown in Fig. 4.

Disease severity of rice sheath rot showed that the highest mean was observed in genotype *Apuapa* (30.86 %) followed by *Moyatsuk* (27.85 %), *Tsushvuri* (26.93 %) and *Yarba* (26.43 %) and the lowest mean of 0.00 % was recorded in *Thangmo*, *Thupfu Lha* and *Chali* followed by *Pfukhi Lha* (3.61 %), *Goyo Tsuk* (5.83 %) and *Amusu* (6.06 %) (Fig. 4, Table 4). For the resistant check RCM-9, the severity was observed to be 11.68 %. The ANOVA result for sheath rot incidence and severity was found to be significant among the tested genotypes (Table 5).

Furthermore, the disease progress curve (AUDPC) values were calculated in relation to sheath rot severity. Results showed that the highest mean AUDPC was recorded in genotype *Apuapa* (371.47) which is at par with *Moyatsuk* (331.57), *Tsushvuri* (326.98) and *Yarba* (319.44) and the lowest was recorded in *Thangmo*, *Thupfu Lha* and *Chali* (0.00) (Fig. 5, Table 4).

Epidemiological study

For epidemiological studies, simple correlation and regression analyses were performed between sheath rot disease severity and meteorological parameters recorded from 12th September to 27th

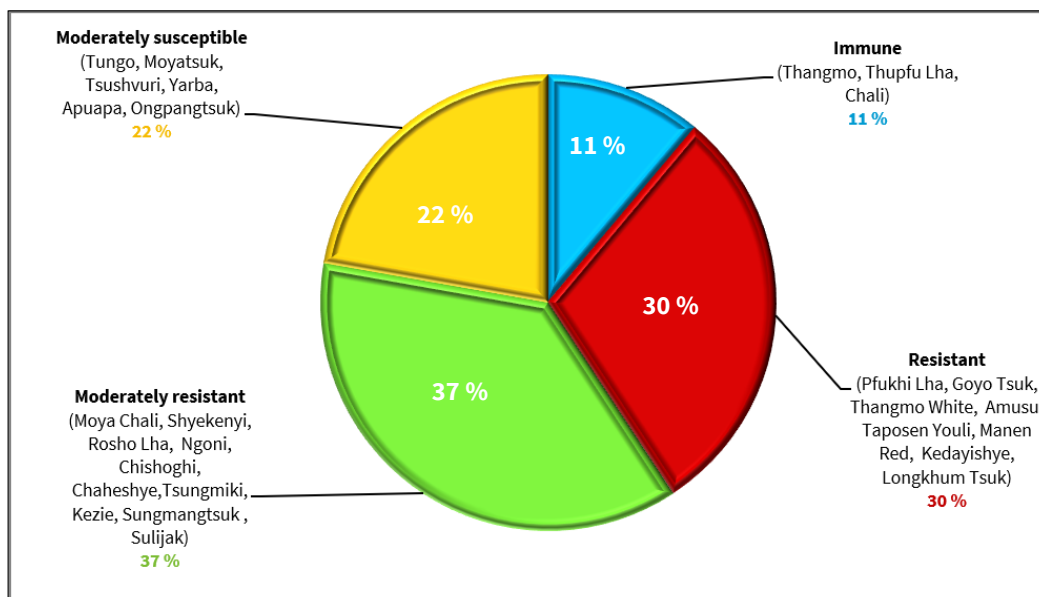


Fig. 3. Pie chart graph representing percentage of rice genotypes falling under different host reactions.

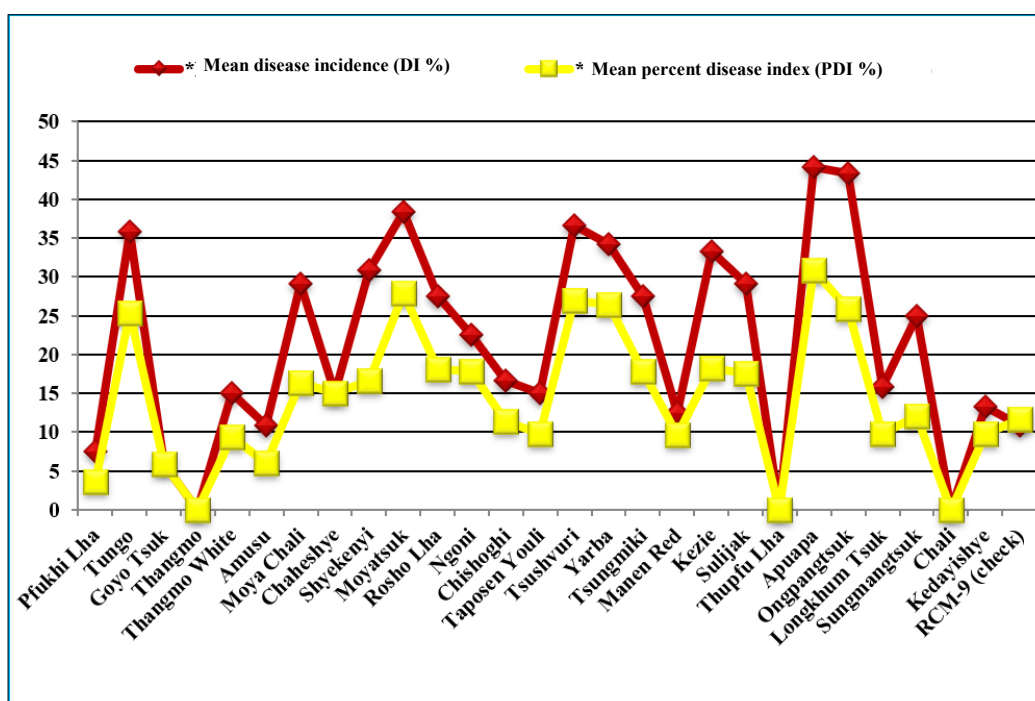


Fig. 4. Line graph showing mean disease incidence and mean percent disease index of rice genotypes for sheath rot.

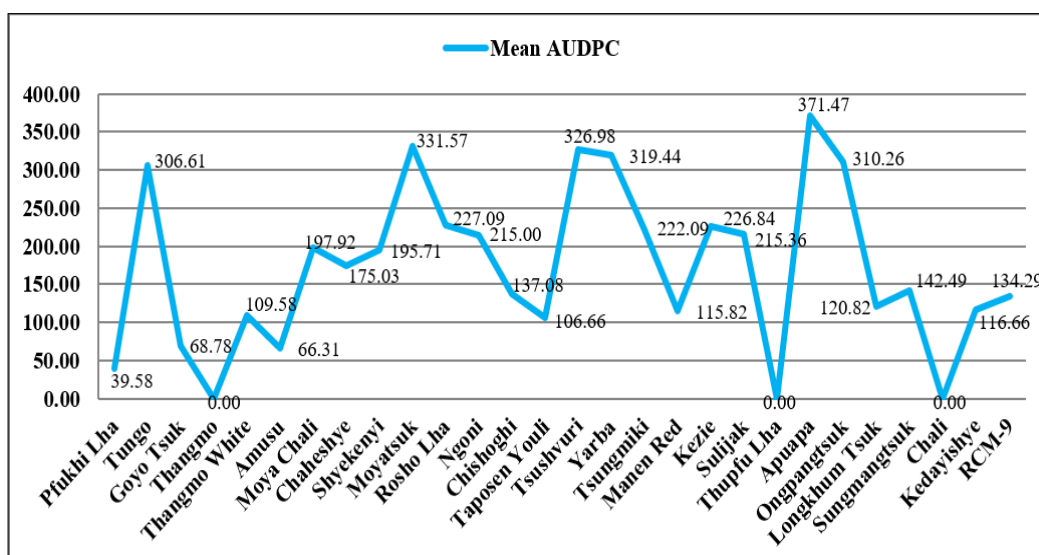


Fig. 5. Line graph representing mean area under disease progress curve of rice genotypes for sheath rot.

Table 4. Disease incidence (DI), percent disease index (PDI) and area under disease progress curve of rice genotypes for sheath rot, *Sarocladium oryzae*

Genotypes	Disease incidence (%)				Mean DI (%)	Percent disease index (%)				Mean PDI%	Area under disease progress curve (AUDPC)				Mean AUDPC
	12 th Sept 2022	27 th Sept 2022	12 th Oct 2022	27 th Oct 2022		12 th Sept 2022	27 th Sept 2022	12 th Oct 2022	27 th Oct 2022		12 th Sept 2022	27 th Sept 2022	12 th Oct 2022	27 th Oct 2022	
Pfukhi Lha	3.33 (6.14)	3.33 (6.14)	6.67 (12.29)	16.67 (19.22)	7.50 (10.95)	0.00 (0.00)	0.00 (0.00)	6.67 (12.29)	7.78 (13.28)	3.61 (6.39)	0.00	0.00	50.00	108.33	39.58
	13.33 (21.14)	26.67 (30.79)	50.00 (45.00)	53.33 (46.92)	35.83 (35.96)	13.33 (21.14)	20.00 (26.57)	28.67 (32.37)	39.52 (38.95)	25.38 (29.76)	100.00	250.00	365.00	511.43	306.61
Goyo Tsuk	0.00 (0.00)	6.67 (12.29)	6.67 (12.29)	10.00 (18.43)	5.83 (10.75)	0.00 (0.00)	6.67 (12.29)	6.67 (12.29)	10.00 (18.43)	5.83 (10.75)	0.00	50.03	100.05	125.03	68.78
Thangmo	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Thangmo White	0.00 (0.00)	10.00 (15.00)	20.00 (26.07)	30.00 (33.21)	15.00 (18.57)	0.00 (0.00)	7.78 (13.28)	13.33 (21.32)	16.22 (23.72)	9.33 (14.58)	0.00	58.33	158.33	221.68	109.58
Amusu	3.33 (6.14)	3.33 (6.14)	10.00 (15.00)	26.67 (31.00)	10.83 (14.57)	0.00 (0.00)	3.33 (6.14)	7.78 (13.28)	13.14 (21.24)	6.06 (10.17)	0.00	25.00	83.33	156.90	66.31
Moya Chali	3.33 (6.14)	20.00 (26.07)	43.33 (41.07)	50.00 (45.00)	29.17 (29.57)	3.33 (6.14)	13.33 (21.32)	23.33 (28.85)	25.56 (30.36)	16.39 (21.67)	25.00	125.00	275.00	366.68	197.92
Chaheshye	0.00 (0.00)	6.67 (12.29)	26.67 (31.00)	26.67 (31.00)	15.00 (18.57)	0.00 (0.00)	6.67 (12.29)	26.67 (31.00)	26.67 (31.00)	15.00 (18.57)	0.00	50.03	250.05	400.05	175.03
Shyekenyi	3.33 (6.14)	20.00 (26.07)	46.67 (43.08)	53.33 (46.92)	30.83 (30.55)	3.33 (6.14)	13.33 (21.32)	21.33 (27.50)	28.38 (32.19)	16.60 (21.79)	25.00	125.00	260.00	372.85	195.71
Moyatsuk	16.67 (23.86)	26.67 (31.00)	50.00 (45.00)	60.00 (50.77)	38.33 (37.65)	13.33 (21.32)	18.67 (25.57)	33.43 (35.31)	45.98 (42.68)	27.85 (31.22)	100.00	240.00	390.73	595.55	331.57
Rosho Lha	13.33 (21.14)	20.00 (26.07)	33.33 (35.01)	43.33 (41.15)	27.50 (30.84)	13.33 (21.14)	15.56 (23.03)	20.00 (26.57)	23.33 (28.85)	18.06 (24.90)	100.00	216.68	266.68	325.00	227.09
Ngoni	6.67 (12.29)	20.00 (26.07)	30.00 (33.00)	33.33 (35.22)	22.50 (26.65)	6.67 (12.29)	13.33 (21.32)	23.33 (28.85)	28.00 (31.94)	17.83 (23.60)	50.00	150.00	275.00	385.00	215.00
Chishoghi	3.33 (6.14)	13.33 (21.14)	20.00 (26.07)	30.00 (33.21)	16.67 (21.64)	3.33 (6.14)	11.11 (19.43)	13.33 (21.32)	17.56 (24.77)	11.33 (17.91)	25.00	108.33	183.33	231.68	137.08
Taposen Youli	0.00 (0.00)	6.67 (8.86)	20.00 (26.07)	33.33 (35.01)	15.00 (17.48)	0.00 (0.00)	4.44 (7.14)	13.33 (21.32)	21.33 (27.49)	9.78 (13.99)	0.00	33.33	133.33	260.00	106.66

<i>Tsushvuri</i>	16.67 (23.86)	26.67 (31.00)	50.00 (45.00)	53.33 (46.92)	36.67 (36.69)	12.22 (20.42)	21.78 (27.81)	32.67 (34.84)	41.06 (39.85)	26.93 (30.73)	91.65	254.98	408.33	552.95	326.98
<i>Yarba</i>	13.33 (21.14)	23.33 (28.78)	46.67 (43.08)	53.33 (46.92)	34.17 (34.98)	13.33 (21.14)	21.11 (27.34)	30.22 (33.32)	41.04 (39.84)	26.43 (30.41)	100.00	258.33	385.00	534.45	319.44
<i>Tsungmiki</i>	10.00 (15.00)	20.00 (26.07)	36.67 (37.22)	43.33 (41.15)	27.50 (29.86)	10.00 (15.00)	15.56 (23.03)	21.56 (27.59)	24.22 (29.47)	17.83 (23.77)	75.00	191.68	278.35	343.35	222.09
<i>Manen Red</i>	3.33 (6.14)	10.00 (15.00)	16.67 (23.86)	20.00 (26.57)	12.50 (17.89)	3.33 (6.14)	7.78 (13.28)	12.22 (20.42)	15.11 (22.86)	9.61 (15.68)	25.00	83.33	149.98	204.98	115.82
<i>Kezie</i>	6.67 (12.29)	30.00 (33.00)	46.67 (42.99)	50.00 (45.00)	33.33 (33.32)	6.67 (12.29)	16.67 (24.03)	24.44 (29.62)	25.43 (30.27)	18.30 (24.05)	50.00	175.00	308.33	374.05	226.84
<i>Suljiak</i>	6.67 (12.29)	26.67 (31.00)	36.67 (37.22)	46.67 (43.08)	29.17 (30.90)	6.67 (12.29)	17.78 (24.85)	20.22 (26.67)	25.52 (30.31)	17.55 (23.53)	50.00	183.33	285.00	343.10	215.36
<i>Thupfu Lha</i>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
<i>Apuapa</i>	20.00 (26.07)	36.67 (37.22)	56.67 (48.85)	63.33 (52.78)	44.17 (41.23)	16.67 (23.86)	24.44 (29.55)	33.56 (35.38)	48.78 (44.30)	30.86 (33.27)	125.00	308.33	435.00	617.55	371.47
<i>Ongpangtsuk</i>	20.00 (26.07)	33.33 (35.01)	56.67 (48.85)	63.33 (52.78)	43.33 40.68	13.33 (21.32)	18.67 (25.57)	29.81 (33.09)	41.85 (40.31)	25.92 (30.07)	100.00	240.00	363.58	537.45	310.26
<i>Longkhum Tsuk</i>	3.33 (6.14)	16.67 (23.86)	20.00 (26.57)	23.33 (28.78)	15.83 (21.34)	3.33 (6.14)	10.00 (18.43)	12.22 (20.42)	13.33 (21.41)	9.72 (16.60)	25.00	100.00	166.65	191.63	120.82
<i>Sungmangtsuk</i>	0.00 (0.00)	16.67 (23.86)	40.00 (39.15)	43.33 (41.15)	25.00 (26.04)	0.00 (0.00)	12.22 (20.42)	15.56 (23.20)	20.44 (26.85)	12.06 (17.62)	0.00	91.65	208.33	270.00	142.49
<i>Chali</i>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
<i>Kedayishye</i>	0.00 (0.00)	13.33 (21.14)	16.67 (23.86)	23.33 (28.78)	13.33 (18.45)	0.00 (0.00)	11.11 (19.43)	12.22 (20.42)	15.56 (23.16)	9.72 (15.75)	0.00	83.33	174.98	208.35	116.66
RCM-9 (check)	0.00 (0.00)	6.67 (12.29)	16.67 (23.86)	20.00 (26.07)	10.83 (15.55)	0.00 (0.00)	6.67 (12.29)	18.22 (25.26)	21.81 (27.82)	11.68 (16.34)	0.00	50.03	186.70	300.25	134.25
SEm±	4.17	4.41	3.52	2.97	3.77	3.69	3.35	2.30	1.50	2.71	-	-	-	-	-
CD (P = 0.05)	11.79	12.50	9.96	8.41	10.67	10.44	9.48	6.50	4.25	7.67	-	-	-	-	-

Figures in the table are mean values of three replications and those in parenthesis are angular transformed values.

Table 5. Mean sum of square estimates from analysis of variance for disease incidence and percent disease index of sheath rot

Source of variance	Degree of freedom	Mean sum of square (MSS)							
		DI of sheath rot on 12 th Sept 2022	DI of sheath rot on 27 th Sept 2022	DI of sheath rot on 12 th Oct 2022	DI of sheath rot on 27 th Oct 2022	PDI of sheath rot on 12 th Sept 2022	PDI of sheath rot on 27 th Sept 2022	PDI of sheath rot on 12 th Oct 2022	PDI of sheath rot on 27 th Oct 2022
Replication	2	27.51	56.70	3.14	8.92	14.93	2.69	0.55	4.41
Treatments	27	284.39*	462.45*	845.43*	932.20*	254.93*	320.98*	434.67*	574.14*
Error	54	55.94	62.80	39.89	28.45	43.84	36.15	16.99	7.27

*Significant at 5% level of significance, DI: disease incidence; PDI: percent disease index.

October 2022, as this period represents the active phase of sheath rot development during the major kharif rice-growing season in Nagaland. Disease severity, being influenced by the cumulative effect of multiple factors, was assessed to determine the individual influence of weather variables on disease progression in the crop.

The correlation analysis of sheath rot severity and weather parameters showed that six genotypes (*Shyekenyi*, *Goyo Tsuk*, *Chishoghi*, *Apuapa*, *Sulijak* and *Sungmangtsuk*) exhibited a positive and significant correlation with maximum relative humidity (Fig. 6, Table 6). Furthermore, Fig. 6 and Table 6 indicated that sheath rot intensity was significantly and negatively correlated with maximum temperature (*Chaheshye*, *Thangmo White*, *Moya Chali*, *Ngoni*, *Tsungmiki*, *Manen Red*, *Kezie* and check RCM-9), minimum temperature (*Moyatsuk*, *Apuapa* and *Ongpangtsuk*) and minimum relative humidity (*Kedayishye*, *Chishoghi*, *Goyo Tsuk*, *Sulijak*, *Sungmangtsuk* and *Longkhum Tsuk*). Thus, weather variables such as T_{max} , T_{min} , RH_{max} , RH_{min} played a significant role in disease progression, which increased with increasing relative humidity and decreased with increasing minimum and maximum temperatures.

The analysed data between disease severity and weather variables, calculated using a simple regression equation, are shown in Table 7. Based on coefficient of determination (R^2), the results showed that fluctuations in sheath rot severity during the study depend on the changes in T_{max} (71 %), T_{min} (78 %), RH_{max} (87 %), RH_{min} (78 %), rainfall (61 %) and number of rainy days (17 %), with high SE values of 5.065, 4.412, 3.302, 4.394, 5.891 and 8.577 respectively.

Discussion

Screening and degree of severity of rice genotypes to sheath rot disease

The present findings revealed varied resistance reactions of rice genotypes against sheath rot disease under natural field conditions, which are consistent with earlier reports which also observed slight to moderate incidence of sheath rot having different disease reactions with three rice germplasms exhibiting immune response under naturally infested field condition (16). Likewise, previous studies also observed diverse resistance responses among 278 genotypes, with 16 genotypes (5.75 %) resistant, 38 genotypes (13.67 %) moderate resistant, 139 genotypes (50 %) moderately susceptible, 78 genotypes (28.06 %) susceptible and 7 genotypes (2.52 %) highly susceptible (19). Similar variation was also observed among 108 genotypes, further supporting the present observations of differential host response (20). Similarly, in a related study, 44 rice genotypes tested also showed varying levels of resistance, ranging from highly resistant to susceptible, although none exhibited immune reaction under controlled and artificial inoculation conditions (21). The occurrence of immune genotypes with no visible symptoms in the field during the present study may be attributed to the less aggressive and non-uniform nature of natural infection compared to artificial inoculation methods, which may have allowed some resistant genotypes to escape symptom development under field conditions.

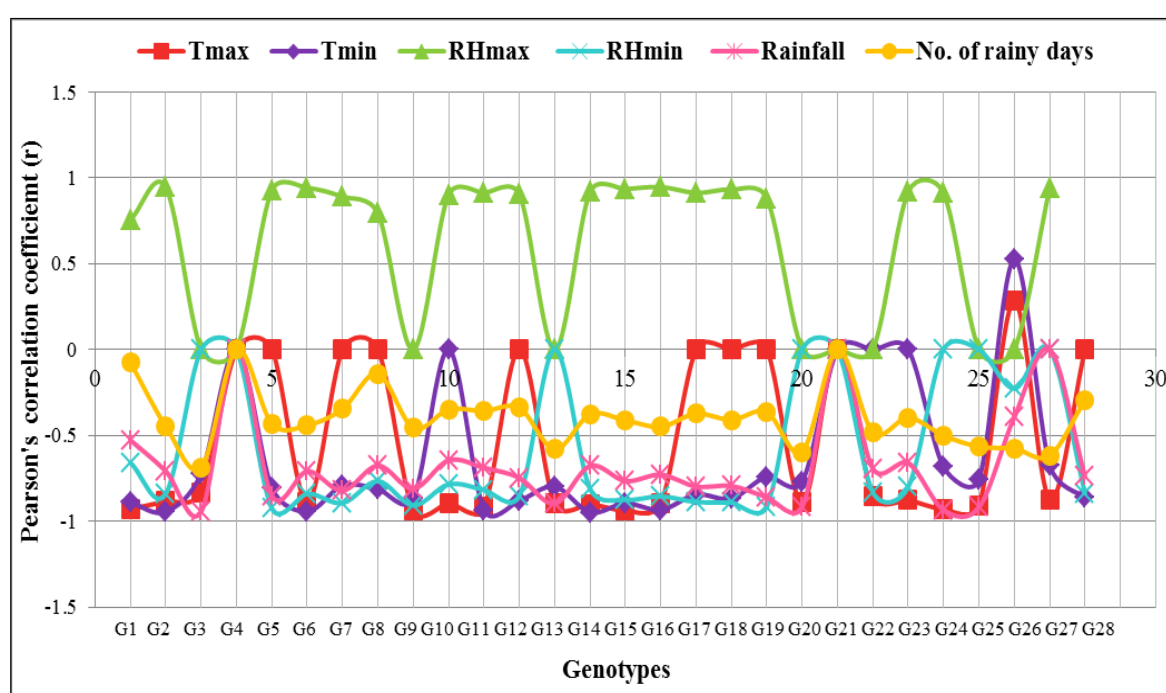
**Fig. 6.** Correlation coefficient (r) graph on sheath rot severity of rice genotypes with weather parameters.

Table 6. Correlation coefficient (r) on percent disease index of sheath rot with weather parameters

Sl No.	Genotypes(G)	Mean PDI (%)	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Number of rainy days
			T _{max}	T _{min}	RH _{max}	RH _{min}		
G ₁	<i>Pfukhi Lha</i>	3.61 (6.39)	-0.930	-0.892	0.757	-0.660	-0.528	-0.076
G ₂	<i>Tungo</i>	25.38 (29.76)	-0.884	-0.945	0.944	-0.840	-0.709	-0.447
G ₃	<i>Goyo Tsuk</i>	5.83 (10.75)	-0.832	-0.721	0.973*	-0.993**	-0.944	-0.688
G ₄	<i>Thangmo</i>	0.00 (0.77)	0.000	0.000	0.000	0.000	0.000	0.000
G ₅	<i>Thangmo White</i>	9.33 (14.58)	-0.960*	-0.806	0.927	-0.926	-0.852	-0.431
G ₆	<i>Amusu</i>	6.06 (10.17)	-0.887	-0.944	0.942	-0.840	-0.709	-0.441
G ₇	<i>Moya Chali</i>	16.39 (21.67)	-0.982*	-0.793	0.890	-0.894	-0.822	-0.346
G ₈	<i>Chaheshye</i>	15.00 (18.57)	-0.989*	-0.812	0.792	-0.767	-0.676	-0.140
G ₉	<i>Shyekenyi</i>	16.60 (21.79)	-0.936	-0.869	0.950*	-0.908	-0.811	-0.457
G ₁₀	<i>Moyatsuk</i>	27.85 (31.22)	-0.894	-0.957*	0.902	-0.785	-0.645	-0.349
G ₁₁	<i>Rosho Lha</i>	18.06 (24.90)	-0.919	-0.935	0.912	-0.817	-0.689	-0.358
G ₁₂	<i>Ngoni</i>	17.83 (23.60)	-0.961*	-0.880	0.904	-0.853	-0.748	-0.340
G ₁₃	<i>Chishoghi</i>	11.33 (17.91)	-0.898	-0.798	0.973*	-0.968*	-0.897	-0.581
G ₁₄	<i>Taposen Youli</i>	9.78 (13.99)	-0.901	-0.948	0.918	-0.812	-0.678	-0.378
G ₁₅	<i>Tsushvuri</i>	26.93 (30.73)	-0.937	-0.896	0.935	-0.875	-0.766	-0.412
G ₁₆	<i>Yarba</i>	26.43 (30.41)	-0.896	-0.934	0.947	-0.855	-0.729	-0.450
G ₁₇	<i>Tsungmiki</i>	17.83 (23.77)	-0.967*	-0.845	0.913	-0.888	-0.798	-0.373
G ₁₈	<i>Manen Red</i>	9.61 (15.68)	-0.951*	-0.868	0.932	-0.892	-0.795	-0.410
G ₁₉	<i>Kezie</i>	18.30 (24.05)	-0.979*	-0.741	0.881	-0.914	-0.860	-0.365
G ₂₀	<i>Sulijak</i>	17.55 (23.53)	-0.892	-0.769	0.969*	-0.978*	-0.917	-0.596
G ₂₁	<i>Thupfu Lha</i>	0.00 (0.77)	0.000	0.000	0.000	0.000	0.000	0.000
G ₂₂	<i>Apuapa</i>	30.86 (33.27)	-0.852	-0.956*	0.950*	-0.832	-0.694	-0.481
G ₂₃	<i>Ongpangtsuk</i>	25.92 (30.07)	-0.878	-0.961*	0.920	-0.801	-0.660	-0.397
G ₂₄	<i>Longkhum Tsuk</i>	9.72 (16.60)	-0.930	-0.685	0.911	-0.969*	-0.935	-0.501
G ₂₅	<i>Sungmangtsuk</i>	12.06 (17.62)	-0.908	-0.756	0.957*	-0.976*	-0.919	-0.566
G ₂₆	<i>Chali</i>	0.00 (0.77)	0.283	0.524	0.000	-0.227	-0.393	-0.577
G ₂₇	<i>Kedayishye</i>	9.72 (15.75)	-0.872	-0.674	0.941	-0.994**	-0.962*	-0.618
G ₂₈	RCM-9	11.68 (16.34)	-0.973*	-0.863	0.880	-0.838	-0.738	-0.293

df = (4-2) = 2; $r_{0.05} = 0.950$; $r_{0.01} = 0.990$. *Significant at 5 % level of significance; **Significant at 1 % level of significance. Those values which do not assign any symbol are non-significant at 5 % level of significance. Figures in the table are mean values of three replications and those in parenthesis are angular transformed values.

RH_{max}: maximum relative humidity; RH_{min}: minimum relative humidity; T_{min}: minimum temperature (°C); T_{max}: maximum temperature (°C).

Table 7. Simple regression between disease severity of sheath rot and weather parameters

Simple regression	Regression equation	Standard error	R ²
Maximum temperature (°C)	$y = 36.846 + (-0.845) x + 5.065$	5.065	0.712
Minimum temperature (°C)	$y = 72.676 + (-2.748) x + 4.412$	4.412	0.782
Maximum relative humidity (%)	$y = -259.920 + (2.948) x + 3.302$	3.302	0.878
Minimum relative humidity (%)	$y = 63.113 + (-0.716) x + 4.394$	4.394	0.783
Rainfall (mm)	$y = 17.825 + (-0.651) x + 5.891$	5.891	0.611
Number of rainy days	$y = 17.065 + (-5.580) x + 8.577$	8.577	0.175

R²: Coefficient of determination; x: weather parameters; y: disease severity.

The findings indicated significant variation in sheath rot severity among rice cultivars, with the highest mean severity (30.86 %) recorded in genotype *Apuapa*. Other authors also showed differential disease reactions among 44 rice varieties, with highest mean severities of 52.28 % in Pusa Basmati-1121 during 2019 and 53.14 % in Pusa Basmati-1401 during 2020 (22). Several other studies have also reported that the disease increases with time which peaks at maturity and that the seed-borne nature of the pathogen severely reduces grain yield and quality, as it infects the crop during panicle initiation (23, 24). Disease severity is influenced by pathogen virulence, host susceptibility and environmental conditions, where highly pathogenic isolates in susceptible hosts result in higher PDI values and rapid symptom development (25). In addition, sheath rot disease incidence and severity index are also influenced by internal and external factors, including varietal susceptibility, agricultural practices and environmental conditions (26).

Epidemiology of rice sheath rot

In support of the current findings that few genotypes positively correlates with maximum relative humidity, other studies also reported that high relative humidity (92–100 %) and little precipitation were favourable for the growth and spread of sheath rot of rice (27). This may be attributed that high relative humidity prolongs moisture retention on the flag leaf sheath and panicle, promoting conidial germination, fungal penetration and rapid pathogen establishment. Previous studies also reported that pathogen severity increases with a decrease in temperature and RH_{min}, with optimum pathogen growth occurring at 12 °C minimum temperature and 27–33 °C maximum temperature, whereby growth was restricted at 36 °C (7). Disease initiation during the heading stage at 17.7 °C minimum temperature and 50 % relative humidity further support the current findings that the disease severity of some genotypes increases during October as temperature and relative humidity decrease (28). Similar observations of significant negative correlation between sheath rot severity and temperatures and evening relative humidity and significant positive correlation with morning relative humidity were also reported earlier (29). Studies further indicated that sheath rot infection is favoured at 22.7–30 °C, whereas further temperature rise may reduce the disease growth rate (30). This could be due to reduced moisture retention and sheath wetness at higher temperatures, which adversely affect conidial germination, fungal growth, enzyme activity and phytotoxin production, thereby reducing pathogen virulence and disease severity. Furthermore, earlier reports also showed no significant correlation between disease severity and certain weather

parameters, like maximum temperature, minimum relative humidity, rainfall and sunshine (31), which is consistent with the present findings that the severity of some rice genotypes could not be correlated with weather variables. This variation may be attributed to the ability of *S. oryzae* to survive in infected seeds, plant residues, soil, water and weeds, enabling infection at various growth stages under favourable conditions, particularly after the booting stage (32).

Conclusion

In conclusion, the present investigation revealed considerable variability among the rice genotypes in response to sheath rot disease under natural field conditions. Among the tested genotypes, *Thangmo*, *Thupfu Lha* and *Chali* exhibited the highest level of resistance showing no visible symptoms as compared to the resistant check variety RCM-9, whereas *Apuapa* was found to be the most susceptible genotype. The epidemiological analysis emphasised the important role of environmental factors in disease development, with maximum relative humidity favouring disease progression, while temperature and minimum relative humidity exhibiting negative correlations with sheath rot severity. The study provides an initial picture on the combined influence of host resistance and prevailing weather conditions on sheath rot disease in local rice genotypes. The identified resistant genotypes may serve as valuable genetic resources which will be useful for future rice breeding programmes aimed at developing resistant cultivars and sustainable disease management strategies. Since host resistance offers an economical and environmentally safe approach for reducing yield losses, further 2–3 year studies should be carried out in the region along with molecular characterisation of resistance and susceptibility genes to these tested genotypes.

Acknowledgements

The authors gratefully acknowledge the infrastructural support provided by the Department of Plant Pathology, Department of Genetics and Plant Breeding and Department of Agronomy, School of Agricultural Sciences (SAS), Nagaland University (NU). The authors also express their sincere gratitude to all the faculty and non-faculty members as well as to all the individuals who have contributed to this research by sharing their valuable insights and suggestions during the course of study.

Authors' contributions

FW, NP, HMD, BS and W contributed to conceptualisation, research and methodology. DL carried out the data analysis. FW, NP and BS carried out the writing, drafting, editing and reviewing of the manuscript. All authors listed have made a substantial, direct and intellectual contribution to the work and approved it for publication.

Compliance with ethical standards

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

Ethical issues: None

References

- Nalley L, Tsioboe F, Durand-Morat A, Shew A, Thoma G. Economic and environmental impact of rice blast pathogen (*Magnaporthe oryzae*) alleviation in the United States. *PLoS One*. 2016;11(12):e0167295. <https://doi.org/10.1371/journal.pone.0167295>
- Zibae A. Rice: importance and future. *J Rice Res*. 2013;1:102. <https://doi.org/10.4172/jrr.1000e102>
- United States Department of Agriculture Economic Research Service. Rice Outlook: April 2025. RCS-25C; 2025.
- Pradhan AK, Mondal B, Bisen J, Jambhulkar NN, Kumar GAK, Mishra SK. Appraising rice consumption pattern in India: trends, preferences and food security. *Oryza*. 2023;60(3):479–86. <https://doi.org/10.35709/ory.2023.60.3.12>
- Ministry of Agriculture and Farmers' Welfare. 3rd Advanced Estimates of Production of Major Agricultural Crops for 2024–25. PIB Online; 2026.
- Directorate of Economics and Statistics, Government of Nagaland. Nagaland Statistical Handbook. 2023. p. 49.
- Gams W, Hawksworth DL. The identity of *Acrocyndrium oryzae* Sawada and a similar fungus causing sheath rot of rice. *Kavaka*. 1975;3:57–61.
- Mvuyekure SM, Sibiya J, Derera J, Nzungize J, Nkima G. Genetic analysis of mechanisms associated with inheritance of resistance to sheath rot of rice. *Plant Breed*. 2017;136:509–15. <https://doi.org/10.1111/pbr.12492>
- Bigirimana VD, Hua GK, Nyamangyoku OI, Höfte M. Rice sheath rot: an emerging ubiquitous destructive disease complex. *Front Plant Sci*. 2015;6:1066. <https://doi.org/10.3389/fpls.2015.01066>
- Peeters KJ, Haeck A, Harinck L, Afolabi OO, Demeestere K, Audenaert K, et al. Morphological, pathogenic and toxigenic variability in the rice sheath rot pathogen *Sarocladium oryzae*. *Toxins*. 2020;12(2):109. <https://doi.org/10.3390/toxins12020109>
- Jeena H, Aravind T, Singh KP. Influence of weather factors on severity of yellow leaf disease of sugarcane. *J Agrometeorol*. 2022;24:217–19. <https://doi.org/10.54386/jam.v24i2.1371>
- Joshi D, Singh P, Singh K, Adhikari S, Rani S. Screening of soybean germplasm for important disease prevalent in North India. *Int J Chem Stud*. 2018;6(2):2731–3.
- Baruah TC, Barthakur HP. A Text Book of Soil Analysis. New Delhi: Vikas Publishing House Pvt Ltd.; 1997.
- International Rice Research Institute. Standard Evaluation System for Rice (SES). Manila: International Rice Research Institute; 2013. p. 52.
- Wheeler BEJ. An Introduction to Plant Diseases. London: John Wiley and Sons Ltd.; 1969. p. 301.
- Fetene YD, Birhan M, Zeleke T. Screening of rice germplasms for their resistance against sheath rot disease (*Sarocladium oryzae*) at Fogera, Ethiopia. *J Plant Pathol Microbiol*. 2020;11:518.
- Campbell CL, Madden LV. Introduction to Plant Disease Epidemiology. New York: John Wiley and Sons; 1990.
- Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd ed. New York: John Wiley and Sons; 1984. p. 20–29.
- Behura A, Prabhukarthikeyan SR, Parameswaran C, Pradhan C, Vaidya N, Keerthana U, et al. Screening of rice genotypes for sheath rot resistance and gene expression analysis of defense responses in resistant and susceptible genotypes. *Physiol Mol Plant Pathol*. 2025;16:102839. <https://doi.org/10.1016/j.pmpp.2025.102839>
- Titaria A, Upmanyu S, Rana SK, Basandrai D. Screening of genotypes for resistance against *Sarocladium oryzae* causing sheath rot of rice. *Himachal J Agric Res*. 2021:110–15.
- Jakkuva S. Studies on sheath rot of rice caused by *Sarocladium oryzae* (Sawada) Gams and Hawksworth [MSc thesis]. Dharwad: University of Agricultural Sciences; 2020.
- Mehta A, Singh SK, Basu U, Ahanger SA, Sharma S, Singh B, et al. Determination of yield losses against sheath rot caused by *Sarocladium oryzae* in rice varieties with differential resistance. *Sci Rep*. 2025;15(1):36309. <https://doi.org/10.1038/s41598-025-05104-y>
- Arunyanart P, Surin A, Disthaporn S. Seed discoloration disease and its chemical control. *Int Rice Res Newsl*. 1981;6(3):14–15.
- Singh K, Mathur SB. Further evidence of transmission of *Sarocladium oryzae* through rice seeds and its quarantine significance. *Indian Phytopathol*. 1992;45(4):454–6.
- Widiastuti A, Pramunadipa S, Wibowo A, Suga H, Priyatmojo A. Short communication: *Sarocladium oryzae* associated with sheath rot disease of rice in Indonesia. *Biodiversitas*. 2020;21(3):1243–9. <https://doi.org/10.13057/biodiv/d210352>
- Pramunadipa S, Widiastuti A, Wibowo A, Suga H, Priyatmojo A. *Sarocladium oryzae* associated with sheath rot disease of rice in Indonesia. *Biodiversitas*. 2020;21(3):1243–9. <https://doi.org/10.13057/biodiv/d210352>
- Sinha BB, Sinha RK. Effect of environment on incidence of sheath rot caused by *Sarocladium oryzae* in rice. *J Appl Biol*. 1996;6:97–9.
- Dhal A, Mohanty AK, Lenka S. Occurrence of sheath rot of rice in semi-deep water situation in Orissa. *Environ Ecol*. 1998;16:233–4.
- Mehta A, Singh SK, Wani OA, Ahanger SA, Basu U, Vaid A, et al. Effect of abiotic factors on progress and severity of sheath rot (*Sarocladium oryzae*) in rice. *J Phytopathol*. 2023;171(7–8):300–19. <https://doi.org/10.1111/jph.13183>
- Das B, Venu E, Das S, Sathiyaseelan K, Das D, Sinha P. Assessing the risk of sheath rot infection in rice agro-ecosystems of the Indian subcontinent in relation to climate change. 2024. <https://ssrn.com/abstract=4931157>
- Singh RA, Raju CA. Studies on sheath rot of rice. *Int Rice Res Newsl*. 1981;6:11–2.
- Pearce DA, Bridge PD, Hawksworth DL. Species concept in *Sarocladium*, the causal agent of sheath rot in rice and bamboo blight. In: *Major Fungal Diseases of Rice: Recent Advances*. Dordrecht: Springer Netherlands; 2001. p. 285–92. https://doi.org/10.1007/978-94-017-2157-8_20

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonpublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.