Mysore J. Agric. Sci., 57 (2) : 385-394 (2023)

Progression of Rice Sheath Blight in Relation to Weather Variables and Exploratory Development of Prediction Equations

M. M. SINDHU, A. NAGARAJA, M. K. PRASANNA KUMAR AND B. S. CHETHANA
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : sindhumm1995@gmail.com

AUTHORS CONTRIBUTION

M. M. SINDHU :
Conceptualization, draft prepation and data analysis;
A. NAGARAJA :
Draft correction and supervision;
M. K. PRASANNA KUMAR
Conceptualization and supervision;
B. S. CHETHANA :
Field facility and seed source

Corresponding Author :
M. M. SINDHU
Department of Plant Pathology, College of Agriculture, UAS, GKVK, Bengaluru

Received : August 2022
Accepted : February 2023

ABSTRACT

Rice sheath blight caused by *Rhizoctonia solani* Kuhn has become an important constraint in rice cultivation in India and other tropical countries. The present study explores the effects of weather factors (temperature, relative humidity, rainfall and bright sunshine hours) on paddy sheath blight severity. During *kharif* 2020-21 at Zonal Agricultural Research Station, V.C. Farm, Mandya, all tested nine genotypes (Jyothi, Jaya, IR 64, Thanu, MTU 1001, MTU 1010, BR 2655, KRH4 and HR12) showed distinct responses to sheath blight disease. The disease started on the 28th November 2020 with a mean severity of 0.31 per cent, gradually increasing to a peak on 11th January 2021 (37.41%). The Jyothi (highly susceptible) genotype showed the highest mean disease severity (20.16%), whereas the BR 2655 which is moderately susceptible, showed the lowest mean sheath blight severity (10.90%). The optimal weather conditions for disease development were maximum temperature (25.50-29.62 °C), minimum temperature (16.50-18.50 °C), morning relative humidity (87.94-93.23%), evening relative humidity (53.74-75.54%), rainfall (2.00-20.50 mm) and sunshine (3.20-10.50 hours). Correlation analysis showed that the maximum air temperature was the key factor in governing the disease in the field among all the meteorological factors. A maximum temperature (25.50-29.62 °C) was found favor the development and spread of sheath blight after its establishment in the field. A predictive model was developed with a coefficient of determination (R^2) of 0.804-0.848 using statistical language R. A step-wise multiple regression analysis approach was adopted to identify the most appropriate predictive variables to constitute the linear regression model.

Keywords : Rice sheath blight, Disease severity, Weather parameters, Correlation, Regression, Prediction equation

RICE (*Oryza sativa* L.) is the most important staple food for more than half of the human population, providing approximately 19 per cent of the daily calories consumed worldwide (https://esa.un.org). It is a crop of Asian origin that belongs to the family Poaceae and about 90 per cent of the global rice area, production and consumption are concentrated in Asia. India is the world's second largest rice producer and consumer next to China. In India it is cultivated in an area of 44.44 Mha with a production of 112 Mt and productivity of 4.1 mt per hectare during 2020-21 (Deepak *et al*., 2021).

Rice crops face several future challenges that will seriously jeopardise their annual production. Among these challenges, fungal diseases threaten rice production which cause decreasing annual yields and increasing cultivation costs. Among these sheath blights is a major production constraint in profusely tillering, fertilizer responsive, high yielding varieties and hybrids under intensive rice production systems. The yield losses ranging from 4-50 per cent have been reported depending on the crop stage at the time of infection, the severity of the disease and environmental conditions (Bhunkal *et al*., 2015). This disease is caused by the soil borne fungus *Rhizoctonia solani* Kuhn [teleomorph: *Thanatephorus cucumeris* (Frank) Donk]. In India, it was first reported from Gurdaspur by Paracer and Chahal (1963) and has become a major production constraint in different paddy growing states of India due to the widespread cultivation of high yielding rice varieties with a narrow genetic base and apparent change in the climate.

Introduction of high-yielding varieties, there has been a considerable increase in the dosage of nitrogen application, the number of plants/unit area and the number of irrigations. All these factors result in luxuriant plant growth, thick stand of the crop and constant humid conditions coupled with high temperature during the rainy (*Kharif*) season. Little was known regarding the influence of meteorological factors that influence the continuous build- up of sheath blight in the field. Weather-based prediction models have been used to forecast rice diseases like bacterial leaf blight and blast disease (Hashimoto *et al.,* 1984 and Calvero *et al.,* 1996) but there was very little initiative to model sheath blight incidence using epidemiological parameters, particularly in Indian condition. Hence, an attempt has been made to elucidate the effect of weather parameters on sheath blight severity and to develop a prediction model that could guide the management decisions and will be very helpful in reducing yield loss.

MATERIAL AND METHODS

Field Experiment

To explicate the influence of weather parameters on the development of sheath blight disease, the field experiment was conducted during the late *kharif* 2020-21 at V.C. Farm, Mandya (12°34' N latitude, 76°50' E longitude and at an altitude of 695.0 m above mean sea level).

Plant Material, Nursery Sowing and Transplanting

The planting materials of nine selected genotypes *viz.,* Jyothi, Jaya, IR 64, Thanu, MTU 1001, MTU 1010, BR 2655, KRH4 and HR12 were collected from Zonal Agricultural Research Station (ZARS), Mandya. Nursery was prepared on raised beds with seeds of each genotype in individual small plots (3 x 3 sq. m). One-month old rice seedlings of individual cultivars were transplanted into the plot of 3m x 3m size. A recommended fertilizer dose of N: P: K at the rate of 58:23:25 kg/acre and routine cultural practices were performed to sustain a vigorous crop stand.

Disease Severity

After transplanting, the onset time of disease was monitored as the appearance of first symptoms and sheath blight severity was assessed in the field. The severity of the disease was scored using a 0-9 rating scale (IRRI, 2013). Twenty plants per plot were randomly selected in the 'Z' pattern to record the disease severity under natural epiphytotic conditions. The whole plant was assessed at 2 days intervals upto 15 days before harvest. Per cent disease index (PDI) was calculated following the standard formula (Mckinney, 1923).

$$\text{PDI} \; \frac{\text{Sum of scores}}{\text{Number of observations assessed X highest number in disease rating scale}} \text{ X } 100$$

Correlation and Regression

Correlation and linear regression among the metrological factors and disease severity were determined to study the epidemiology of the rice sheath blight pathosystem. The weather variables *i.e.*, maximum temperature (°C), minimum temperature (°C), morning and evening humidity (%), rainfall (mm) and sunshine hours were obtained from the Meteorological Observatory, V.C. Farm, Mandya for the period of investigation. Meteorological factors significantly affecting the disease severity were identified and established by the correlation and linear regression analysis. The meteorological factors were set as independent variables and disease severity served as the dependent variable (Alase *et al.*, 2021 and Jayashree *et al.*, 2022).

Statistical Analysis

All the collected data sets were statistically subjected to the correlation of disease severity with the weather factors and linear regression analysis to identify the responsive variable using the R version 4.1.0 (R Core Team, 2020).

TABLE 1

Scale for scoring rice sheath blight as per IRRI (2013)

Scale	Relative lesion height
0	No infection
1	Vertical spread of the lesion up to 20% of plant height
3	Vertical spread of the lesion up to 21 - 30% of plant height
5	Vertical spread of the lesion up to 31 - 45% of plant height
7	Vertical spread of the lesion up to 46 - 65% of plant height
9	Vertical spread of the lesion up to 66 - 100% of plant height

RESULTS AND DISCUSSION

Response of Various Rice Genotypes to Sheath Blight Disease

Conducive environmental conditions facilitate early disease initiation, rapid disease development and the highest disease pressure in the highly susceptible genotypes (Jyothi, HR 12, Jaya, MTU 1001, IR 64, and KRH 4). In moderately susceptible genotypes (BR 2655, MTU 1010 and Thanu), delayed disease initiation, slower disease development rates and lower mean disease severities were recorded. Jyothi showed maximum disease severity (45%) followed by Jaya (42.78%), IR 64 (40.56%), MTU 1001 (40.53%), HR12 (39.44%), and KRH 4 (38.33%) indicating the highly susceptible response. Similarly, the minimum disease severity was recorded on BR 2655 (29.44%), MTU 1010 (30%) and Thanu (30.56%), which showed moderately susceptible response to rice sheath blight disease (Table 2 and Fig. 1). The findings were in accordance with the results of Prasad *et al*. (2010) conducted an experiment on evaluation of rice genotypes against *Rhizoctonia solani*, which indicated that the rice varieties such as HR 12 and IR 64 were susceptible to sheath blight.

TABLE 2

Weather parameters during assessment period and sheath blight disease severity

Date	Tmax (°C)	Tmin (°C)	RHI (%)	RHII (%)	RF (mm)	SSH (Hours)	IR 64	HR-12	KRH - 4	Thanu	BR-2655	MTU 1001	Jyothi	MTU 1010	Jaya	Mean
28/11/2020	25.50	17.25	90.50	74.75	2.00	10.50	0.28	0.28	0	0.00	0.00	0.28	1.39	0.00	0.56	0.31
2/11/2020	27.25	17.88	91.04	65.27	0.00	10.00	1.67	1.39	0.83	0.00	0.00	1.67	2.50	0.00	1.39	1.05
6/12/2020	27.13	17.75	93.09	75.54	0.50	0.00	4.44	4.72	3.06	2.50	1.67	3.89	4.72	1.11	4.17	3.36
10/12/2020	28.38	18.50	93.23	65.39	14.50	9.00	7.22	6.67	6.11	4.44	3.61	6.94	6.94	4.17	6.94	5.89
14/12/2020	27.63	16.50	91.39	53.74	16.00	0.00	10.00	9.72	8.33	5.83	4.72	10.28	10.00	5.28	9.44	8.18
18/12/2020	28.00	17.00	90.64	62.96	10.50	0.00	12.50	13.33	11.11	6.94	5.83	15.28	13.89	7.22	12.50	10.96
22/12/2020	28.13	17.50	91.45	63.14	12.80	0.00	18.33	19.17	13.06	10.28	9.44	19.72	20.83	10.28	21.39	15.83
26/12/2020	29.13	17.50	92.93	55.46	18.00	0.00	25.00	27.22	17.5	15.83	11.94	23.89	26.11	14.44	25.00	20.77
30/12/2020	29.62	17.87	89.58	68.67	20.5	0	29.44	31.11	24.17	19.72	17.22	28.06	32.22	18.06	28.89	25.43
03/1/2021	28.37	16.50	87.94	70.29	11.5	12.4	32.22	32.22	30.28	23.33	21.39	32.24	37.22	22.22	34.44	29.50
07/1/2021	29.25	17.25	90.60	72.96	9.5	3.2	36.67	35.56	34.44	26.67	25.56	36.69	41.11	26.11	38.89	33.52
11/1/2021	28.50	17.625	88.29	69.5	0	0	40.56	39.44	38.33	30.56	29.44	40.53	45.00	30.00	42.78	37.41
		Mean PDI					8.19	18.40	15.60	12.18	10.90	18.29	20.16	11.57	18.87	16.02

Tmax= Maximum temperature, Tmin= Minimum temperature, RHI= Morning relative humidity, RHII= Evening relative humidity, RF= Rainfall and SSH= Sunshine hours

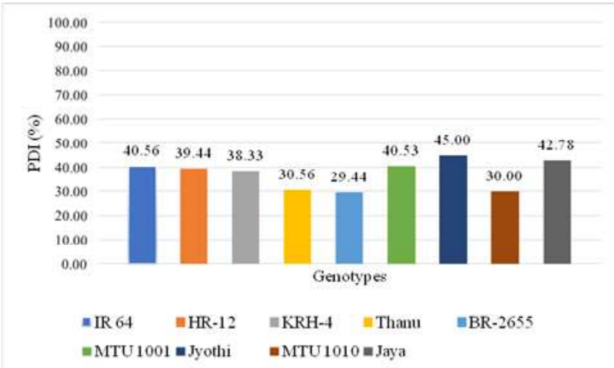

Fig.1 : Sheath blight Severity of different rice genotypes

Progress of Rice Sheath Blight Disease under Natural Condition

In the present investigation, disease development in relation to weather parameters was studied as described in 'Material and Methods'. This study depicts the relationship between the weather parameters like maximum and minimum temperature (Tmax and Tmin), morning and evening relative humidity (RHI and RHII), total rainfall (RF) and bright sunshine hour (SSH) with sheath blight disease severity. The frequency of disease intensity (PDI) was scored from 28th November *kharif* 2020 to 6th December *Kharif* 2020 at two days interval for nine genotypes were worked out at four days intervals and represented in Table 2.

Different rice genotypes showed varying responses to rice sheath blight disease under the influence of significant meteorological conditions. During the investigation, disease progress in relation to weather parameters revealed that initially, on 28th November *kharif* 2020, disease severity was very low (0.31%), which increased gradually to 37.41 per cent (11-1-2021). The sheath blight disease incidence initiated on 28th November *kharif* 2020 is highly susceptible genotypes (Jyothi, HR 12, Jaya, MTU 1001 and IR 64) and from 6th December *kharif* 2020 in moderately susceptible genotypes (Thanu, BR 2655 and MTU 1010). In all the nine genotypes, the per cent disease severity (PDS) showed linear progression throughout the cropping season. From Table 2, it is evident that gradual progress in mean disease severity was observed from 28th November *kharif* 2020 onwards. It was coincided with favorable weather conditions *viz*., maximum temperature (25.25 - 26.50 ºC), minimum temperature (17-18 ºC), morning relative humidity (90-91%) and evening relative humidity (65-85%). The maximum mean disease severity of rice sheath blight occurred on 11th January 2021 with the weather parameters like maximum temperature (25.50-29.62 ºC), minimum temperature (16.50-18.50 ºC), morning relative humidity (87.94-93.23%) and evening relative humidity (53.74-75.54%).

An increase in disease severity is mainly attributed to weather conditions predominating in an area or particular year. *Rhizoctonia* is a soil borne pathogen that can survive in the soil for years. The amount of infective propagules available in the soil or crop debris tends to be a crucial factor affecting the growth and development of sheath blight disease in rice. The survival of this infective propagule in the soil is influenced by the environmental factors suitable for the pathogen's growth. Temperature is a major physiological factor affecting crop production (Yitbarek *et al*., 1988). When the weather condition is humid and temperatures are stressful to the crop (25-30 ºC), sheath blight tends to develop which is been recorded as one of the most destructive pathogen. Gill *et al*. (2001) viewed *R. solani* anastomosis group (AG8), concluding that significant damage was caused when the temperature was lower than 6 to 19 °C at the root region, or when the temperature ranges from 16 to 27 °C.

Correlation of Rice Sheath Blight with Weather Parameters

The sheath blight disease severity of all nine geno types and overall mean disease severity were separately correlated with weather variables *i.e.*, maximum temperature (°C), minimum temperature (°C), morning and evening humidity (%), rainfall (mm) and sunshine hours during the investigation period. The correlation coefficients in relation to weather parameters of nine genotypes are presented in Table 3.

TABLE 3

Correlation of weather parameters with sheath blight disease severity recorded on nine genotypes

Weather Parameters	IR 64	HR-12	KRH-4	Thanu	BR2655	MTU 1001	Jyothi	MTU 1010	Jaya	Mean
X_1	0.767 **	0.786 **	0.711 **	0.723 **	0.683 *	0.758 **	0.742 **	0.710 **	0.743 **	0.742 **
X_2	-0.185	-0.183	-0.214	-0.182	-0.180	-0.216	-0.203	-0.188	-0.197	-0.196
X_3	-0.595 *	-0.577 *	-0.655 *	-0.625 *	-0.655 *	-0.609 *	-0.628 *	-0.638 *	-0.604 *	-0.621 *
X_4	0.068	0.040	0.145	0.133	0.182	0.056	0.105	0.131	0.087	0.101
X_5	0.261	0.302	0.173	0.190	0.127	0.253	0.229	0.173	0.233	0.222
X_6	-0.275	-0.302	-0.207	-0.224	-0.195	-0.287	-0.242	-0.214	-0.257	-0.249

**: Correlation is significant at the 0.01 level (2-tailed); *: Correlation is significant at the 0.05 level (2-tailed). X_1= Maximum temperature (°C), X_2= Minimum temperature (°C), X_3= Morning relative humidity (%), X_4= Evening relative humidity (%), X_5= Rainfall (mm) and X_6= Bright sunshine hours (Hours).

The per cent disease severity correlated positively and was highly significant with maximum temperature in all nine genotypes with correlation coefficient (r) ranging from -0.683 to -0.786 in BR 2655 and HR12, respectively. Whereas, in relation to morning relative humidity, per cent disease severity of all nine genotypes showed a significantly negative correlation with correlation coefficient (r) ranging from -0.577 (HR12) to -0.655 (KRH 4 and BR 2655). In all nine genotypes under study, minimum temperature and bright sunshine hours showed a negative correlation in disease progression whereas, evening relative humidity and rainfall showed positive correlation in relation to disease development (Table 3 and Fig. 2).

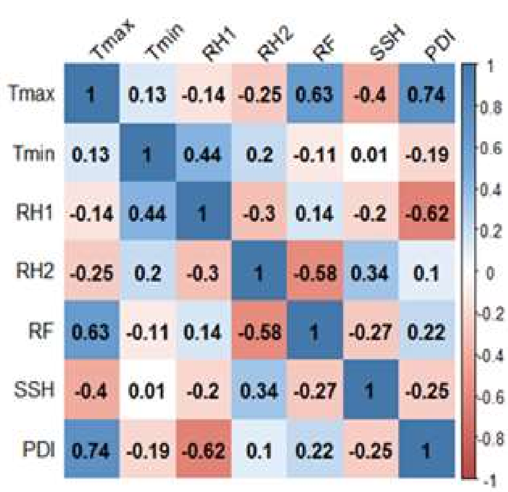

Fig. 2 : Heat map depicting the correlation between mean sheath blight disease severity with weather parameters

The mean per cent disease severity showed a strong positive association of maximum temperature with a correlation coefficient (r) of 0.742 and a negative association of morning relative humidity (-0.621). Whereas, minimum temperature and bright sunshine hours showed a positive correlation and evening relative humidity and rainfall showed negative correlation with mean per cent disease severity however, they remained non-significant in contributing to the disease development (Fig.1). Such results signify that a relatively higher air temperature was more conducive to intensify disease incidence. The results of this study confirmed with findings of Thakur *et al*., (2017) where the correlation analysis between weather parameters and rice sheath blight disease during *Kharif* 2013, 2015 and 2016 revealed that Tmax (30.50- 32.60 °C) and SSH (4.2-9.6 hrs) had a positive effect in the development of sheath blight disease of rice whereas, minimum temperature, morning and evening relative humidity had negative effect on disease development in all *Kharif* seasons of 2013-2016. Yadav *et al*. (2019) also analyzed the correlation of root rot of fenugreek with weather variables and observed a significant positive correlation with Tmax = 0.668 and negative correlation with Tmin = -0.039, RHm -0.457, RHe -0.261 and RF- 0.333. A field experiment was conducted during the rainy (*kharif*) of 2007 and 2008 on rice sheath blight. Correlation analysis showed that, a maximum temperature around 34 °C and a minimum temperature around 26 °C favourable for the spread of sheath blight after its establishment in the field. Again, high morning relative humidity of more than 90 per cent facilitates the spreading the disease (Biswas *et al*., 2011).

The relationship of maximum temperature with disease severity on most genotypes was positively correlated (Fig.3a). A increase in temperature resulted in increased disease severity (Table 2). The mean disease severity was increased when the temperature increased from 25.50 °C (28-11-2020) to 28.50 °C (11-1-2021). In parallel with maximum temperature, the correlation of morning relative humidity with disease severity on most genotypes was negative (Fig. 3c). Though minimum temperature, evening relative humidity and rainfall play a significant role in rice sheath blight epidemics, they were non-significant in contributing to sheath blight severity in the present study (Table 3). A possible reason could be the presence of autocorrelation within these independent variables. Most of the data points lie within 16.50- 18.50 °C (minimum temperature), evening relative humidity (63-75%) and rainfall (10-20 mm) (Table 2). Although these

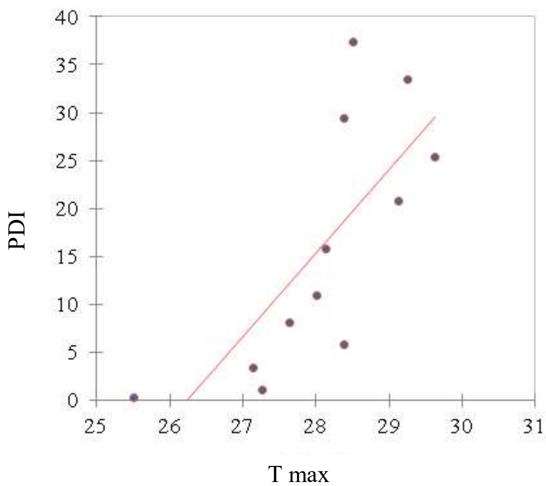

Fig. 3a : Relationship of maximum temperature with mean rice sheath blight severity

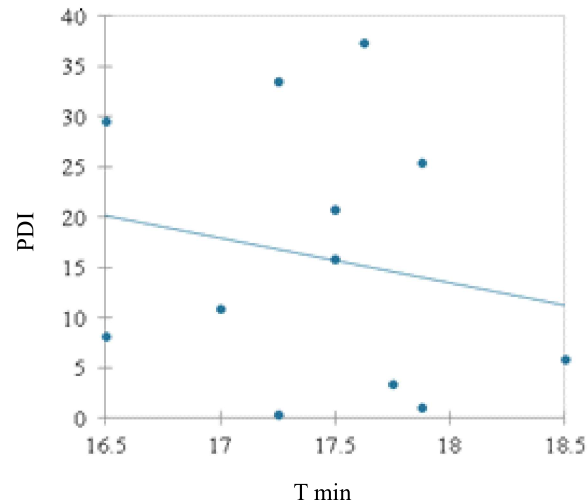

Fig. 3b : Relationship of minimum temperature with mean rice sheath blight severity

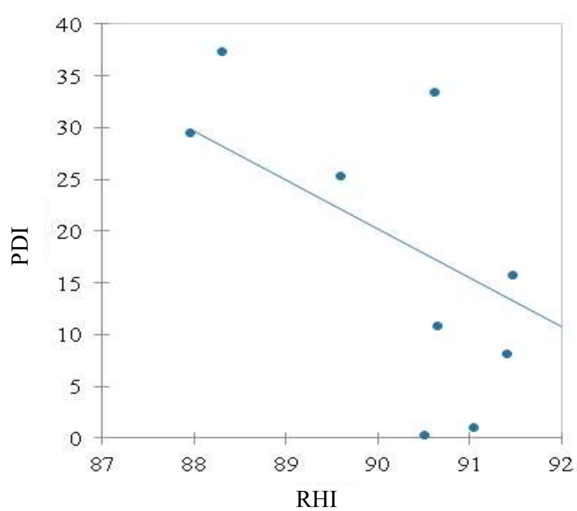

Fig. 3c : Relationship of morning relative humidity with mean rice sheath blight severity

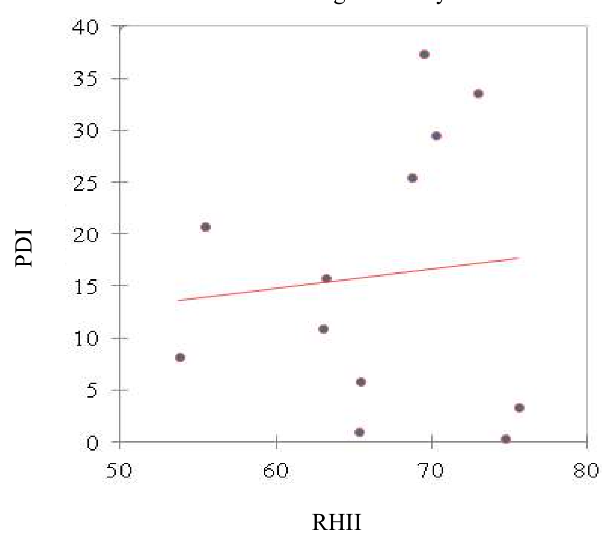

Fig. 3d : Relationship of evening relative humidity with mean rice sheath blight severity parameters contribute to sheath blight severity at field conditions, no significant difference was observed between these variables between time intervals, making them statistically irresponsive to rice sheath blight severity.

Overall, from Table 3 it is observable that when, weather conditions *viz*., maximum temperature (25.50-29.62 ºC), minimum temperature (16.50 - 18.50 ºC), morning relative humidity (87.94-93.23%), evening relative humidity (53.74-75.54%), rainfall (2-20.50 mm) and sunshine (3.20-10.50 hrs) prevails in an area result in rice sheath blight severity.

The mean per cent disease severity showed a strong positive association of maximum temperature with a correlation coefficient (r) of 0.742 and a negative association of morning relative humidity (-0.621). Whereas, minimum temperature and bright sunshine hours showed a positive correlation and evening relative humidity and rainfall showed negative correlation with mean per cent disease severity however, they remained non-significant in contributing to the disease development (Fig.+1). Such results signify that a relatively higher air temperature was more conducive to intensify disease incidence. The results of this study confirmed with findings of Thakur *et al*. (2017) where the correlation analysis between weather parameters and rice sheath blight disease during *kharif* 2013, 2015 and 2016 revealed that Tmax (30.50-32.60 °C) and SSH (4.2-9.6 hrs) had a positive effect in the development of sheath blight disease of rice whereas, minimum temperature, morning and evening relative humidity had negative effect on disease development in all *kharif* seasons of 2013-2016. Yadav *et al*. (2019) also analyzed the correlation of root rot of fenu greek with weather variables and observed a significant positive correlation with Tmax = 0.668 and negative correlation with Tmin = -0.039, RHm -0.457, RHe -0.261 and RF -0.333. A field experiment was conducted during the rainy (*Kharif*) of 2007 and 2008 on rice sheath blight. Correlation analysis showed that, a maximum temperature around 34°C and a minimum temperature around 26 °C favourable for the spread of sheath blight after its establishment in the field. Again, high morning relative humidity of more than 90 per cent facilitates the spreading the disease (Biswas *et al*., 2011).

The relationship of maximum temperature with disease severity on most genotypes was positively correlated (Fig. 3a). A increase in temperature resulted in increased disease severity (Table 2). The mean disease severity was increased when the temperature increased from 25.50 °C (28-11-2020) to 28.50 °C (11-1-2021). In parallel with maximum temperature, the correlation of morning relative humidity with disease severity on most genotypes was negative (Fig. 3c). Though minimum temperature, evening relative humidity and rainfall play a significant role in rice sheath blight epidemics, they were non-significant in contributing to sheath blight severity in the present study (Table 3). A possible reason could be the presence of auto correlation within these independent variables. Most of the data points lie within 16.50-18.50 °C (minimum temperature), evening relative humidity (63-75%) and rainfall (10-20 mm) (Table 2). Although these parameters contribute to sheath blight severity at field conditions, no significant difference was observed between these variables between time intervals, making them statistically irresponsive to rice sheath blight severity.

Overall, from Table 3 it is observable that when, weather conditions *viz*., maximum temperature (25.50-29.62 ºC), minimum temperature (16.50-18.50 ºC), morning relative humidity (87.94-93.23%), evening relative humidity (53.74-75.54%), rainfall (2-20.50 mm) and sunshine (3.20-10.50 hrs) prevails in an area result in rice sheath blight severity.

Multiple Regression Analysis

The multiple regression analysis was performed for six independent weather variables to identify critical and much contributing weather variable (s) separately towards the dependent variable *i.e*., sheath blight disease severity, for all the nine genotypes. In multiple regression analysis except for the maximum temperature and morning relative humidity, other parameters were non-significant in contributing to the

TABLE 4

Stepwise multiple linear regression equations for the prediction of sheath blight severity

Genotypes	Regression equation	R	R^2
IR 64	$Y = 143.653 + 8.907\ X_1 - 4.132\ X_2$	0.914	0.835
HR 12	$Y = 120.499 + 9.168\ X_1 - 3.955\ X_2$	0.918	0.848
KRH 4	$Y = 203.697 + 7.584\ X_1 - 4.412\ X_2$	0.908	0.824
Thanu	$Y = 140.960 + 6.254\ X_1 - 3.349\ X_2$	0.897	0.805
BR 2655	$Y = 165.323 + 5.562\ X_1 - 3.417\ X_2$	0.889	0.790
MTU 1001	$Y = 158.573 + 8.660\ X_1 - 4.218\ X_2$	0.914	0.836
Jyothi	$Y = 203.793 + 9.485\ X_1 - 4.950\ X_2$	0.913	0.834
MTU 1010	$Y = 150.045 + 5.972\ X_1 - 3.368\ X_2$	0.897	0.804
Jaya	$Y = 172.066 + 9.086\ X_1 - 4.492\ X_2$	0.900	0.810
Mean	$Y = 162.101 + 7.853\ X_1 - 4.033\ X_2$	0.909	0.826

X_1= Maximum temperature (°C); X_2= Morning relative humidity (%)

disease severity. This is attributed to the multi co-linearity factor that existed in between the independent variables. Further data was subjected to stepwise regression analysis to find significant contributing variables. Results revealed that maximum temperature and morning relative humidity were the parameters that contributed more to disease severity. Based on this result, prediction equations were formulated for all nine genotypes by employing significant variables *viz*., maximum temperature and morning relative humidity. The regression coefficient based on stepwise regression analysis for per cent disease severity of sheath blight with respect to significant weather parameters *viz.,* maximum temperature and morning relative humidity has been worked out and presented in Table 4.

The results indicated a multiple linear regression equation, with R-value ranging from 0.897-0.918 in all nine genotypes, indicating a strong association between per cent disease severity with maximum temperature and morning relative humidity. The coefficient of determination value (R^2) was found to be, 0.804-0.848 indicating that 80.40-84.80 per cent of the variation in sheath blight disease severity was explained by the function of the weather parameters *viz*., maximum temperature and morning relative humidity. Using these multiple regression models makes it possible to predict disease in advance and the epidemic nature of the disease could be prevented by timely application of the management measures. The generated results are supported by the findings of Biswas *et al*. (2011), who developed the multiple regression equation in variety PR 115 and PR 116 for sheath blight disease severity (R^2 = 80.48 %). Bhukal *et al*. (2015) also developed a regression equation for the sheath blight disease in rice varieties like HKR 127 and Basmati CSR 30 with a model efficiency of 59 - 98 per cent (R^2: 0.59-0.98). The root rot of fenugreek was greatly favoured by maximum temperature (28.8 to 30.50 ÚC) and negative with rainfall. The coefficient of multiple determinations (R^2) was 61.02 and 75.04 per cent during 2016-17 and 2017-18 (Yadav *et. al*., 2019).

The mean sheath blight PDI values were compared with predicted values. The predicted values were fluctuated around the observed values indicating a good association between them. So, this model can be used to predict sheath blight incidence and thus fungicide application schedule can be arranged accordingly and subject to further evaluation under field conditions (Fig. 4).

The present study revealed that a Tmax range between 25-30 °C played a major role in the progression of sheath blight disease. The dynamic process of plant

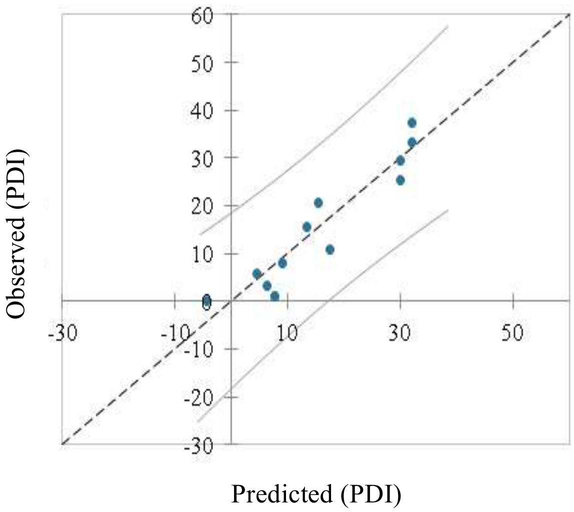

Fig. 4 : Performance of the predictive model (Mean Y = 162.101 + 7.853 X 1-4.033 X2)

disease depends upon the interactions among the host, pathogen and the environment. The variation in any one of the factors influences disease development. Meteorological conditions during rice cultivation periods are subject to change annually and on an hour basis. It is difficult to determine when and how meteorological conditions influence the outbreak of rice sheath blight. Rice sheath blight epidemics differ from field to field even under the same meteorological conditions as the cultivation methods differ. The disease management strategies according to changing climatic conditions with the amalgamation of new strategy will be useful for sustainable food production. Thus, if a sound forewarning system is developed, the epidemic nature of the disease could be prevented by the timely application of the management measures. Such a system will help reduce production cost and promote environmental safety by reducing chemical usage.

Acknowledgement: The funding for the work was facilitated by the project Next Generations Technology in Adaptive Agriculture-Center for Advance Agriculture Science and Technology (NGT-CAAST) funded by ICAR-NAHEP, New Delhi supported by World Bank.

References

Alase, S., Nagaraja, A., Pramesh, D. and Prasanna Kumar M. K., 2021, Influence of weather parameters on false smut disease development in Rice. *Mysore J. Agric. Sci.,* **55** (4) : 320 - 325.

Bhunkal, N., Singh, Ram and Mehta, N., 2015, Assessment of losses and identification of slow blighting genotypes against sheath blight of rice. *J. Mycol. Plant Pathol*., **45** : 285 - 292.

Biswas, B., Dhaliwal, L. K., Chahal, S. K. and Pannu, P. P. S., 2011, Effect of meteorological factors on rice sheath blight and exploratory development of a predictive model. *Indian J. Agric. Sci*., **81** (3) : 256.

Calvero, S. B., Coakley, S. M. and Teng, P. S., 1996, Development of empirical forecasting models for rice blast based on weather factors. *Plant Pathol*., **45** : 667 - 678.

Deepak, C. A., Prasannakumar, M. K., Mahesh, H. B., Chethana, B. S., Pramesh, D., Sahan A, N. B., Manojkumar, H. B. and Rajendra Prasad, S., 2021, Rice blast disease in India: Present status and future challenges. *Rice*, pp. : 1 - 42.

Gill, J., Sivasithamparam, K. and Smettem, K., 2001, Effect of Soil Moisture at Different Temperatures on *Rhizoctonia* Root Rot of Wheat Seedlings. *Plant. Soil*, **231** : 91 - 96.

Hashimoto, A., Hirano, K. and Matsumoto, K., 1984, Studies on the forecasting of rice leaf blast development by application of the computer simulation. *SP Bulletin Fukushima Pref. Agricultural Experiment Station.* **26** : 1 - 104.

https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf

IRRI, I., 2013, Standard evaluation system for rice: International Rice Research Institute. PO Box, **933** : 25.

Jayashree, A., Nagaraja, A, Prasanna Kumar M. K. and Chethana B. S., 2022, Unravelling relationship of weather factors with rice blast disease severity and development of prediction equations. *Mysore J. Agric. Sci.,* **56** (2) : 1 - 13.

MCKINNEY, H. H., 1923, A new system of grading plant diseases. *Agric. Res*., **26** : 95 - 98.

PARACER, C. S. AND CHAHAL, D. S., 1963, Sheath blight of rice caused by *Rhizoctonia solani* Kuhn. A new record of India. *Curr. Sci.,* **32** : 328 - 329.

PRASAD, P. S., NAIK, M. K., THIMMEGOWDA, P. R. AND NAGARAJU, P., 2010, Evaluation of rice genotypes against *Rhizoctonia solani*. *J. Plant Dis. Sci.,* **5** (1) : 61 - 64.

CORE TEAM, R., 2020, R: A language and environment for statistical computing. R: Foundation for Statistical Computing, Vienna, Austria. URL https://www.Rproject.org/.

THAKUR, L., LAKPALE, N., TIWARI, P. K. AND PRADHAN, A., 2017, Epidemiological studies on sheath blight disease of rice in Chhattisgarh Plains Agroclimatic Zone of Chhattisgarh, India. *Int. J. Curr. Microbiol. App. Sci.*, **6** (11) : 1351 - 1361.

YADAV, S. L., GHASOLIA, R. P., YADAV, R. AND YADAV, P., 2019, Studies on survey and epidemiology of *Rhizoctonia solani* causing root rot of fenugreek. *Int. J. Seed Spices*, **9** : 91 - 95.

YITBAREK, S., VERMA, P., GUGEL, R. AND MORRALL, R., 1988, Effect of soil temperature and inoculum density on pre-emergence damping-off of canola caused by *Rhizoctonia solani*. *Canadian, J. Plant Pathol*., **10** : 93 - 98.