Development of a Disease Prediction Model for Brown Spot Disease severity of Rice based on Weather Variable Parameters

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Abstract**—** *The correlation studies of brown spot disease incidence of rice with weather factors found that during the first year of studies (2014-15) the disease incidence was significant and negatively correlated with temperature (Tmax.=-.98), (Tmin.=-.93) and wind speed (WS=-.71) whereas others weather factors RHmax, RHmin., Rainfall (RF) were non significant and positively correlated with brown spot disease severity. Therefore, Tmax., Tmin. and Wind speeds are the key weather factors that influenced the brown spot disease severity of Rice. The multiple analysis stepwise equation showed that maximum temperature was found to be an important key factor for brown spot developments during (2014-15) which is supported by highly significant coefficient value of determination also maximum temperature (Tmax.) was found important predictor in case of Propiconazole application and it could be able to explain variation by more than 95% for the Kharif season (2014-15). The value* R^2 *= 0.96 which indicate that the model is fitted well and is good for predicting brown spot incidence providing 95.6% prediction.*

Keywords**— *Brown spot, Helminthosporium oryzae, Prediction model, weather variable, disease index, correlation, coefficient.***

I. INTRODUCTION

A weather base forecasting system is an important aspect that can reduce by optimising the timing and frequency by reducing chemicals usage. The aim of forecasting system is to reduce fungicides use and accurate prediction is important to synchronize the use of disease control measures to avoid crop losses (Taylor *et al.* 2003). A prediction model based on the relationship between environmental conditions at the time of management and late season disease severity could be used to guide management decisions. Thus, if a sound forewarning system is developed, the explosive nature of the disease could be prevented by timely application of control measures. In this regard Multiple Regression Analysis (MRA) approaches are being used to help, synthesize and develop understanding of the complex plant-pathogen-environment relations. The resultant models enable exploration of the factors that govern disease epidemics and the design of control systems that minimize yield losses. The same models have potential to guide breeding programs and work to develop strategies that will prolong the usefulness of disease resistance gene. Thus in the present studies on brown spot disease of Rice prediction models based on weather parameters was developed. Brown spot disease of rice caused by *Heminthosporium oryzae* (Breda de Haan) is a major fungal disease which has been reported to occur in all rice growing countries including Japan, China, Burma, Sri Lanka, Bangladesh, Iran, Africa, South America, Russia, North America, Philipines, Saudi Arabia, Australia, Malaysia and Thailand (Ou, 1985; Khalili, *et al.* 2012). In India the disease was known to occur in all rice growing states but more severe in dry and direct seeded rice in the state of Bihar, Chhatisgarh, Madhya Pradesh, Orissa, Assam, Jharkhand and West Bengal (Gangopadhyay, 1983; Ou, 1985; Ghose *et al.*, 1960). This particular disease has been reported to cause enormous losses in grain yield upto 90% particularly when leaf spotting phase assumes epiphytotic proportions as observed in great Bengal famine in 1942 (Ghose *et al.* 1960), in general it can cause yield loss upto 45% when no protection was given. The **w**eather influences all stages of host and brown spot pathogen life cycles as well as the development of disease (Chakrabarty *et al.* 2000). A warning system is previously developed and is being used to schedule fungicide applications for controlling Lettuce downy mildew caused by *Bremia letucae* Regal in coastal California (Scherm *et al.* 1995). The problem, nature and epidemiologist specific questions determine the mathematical tool to be used for modelling plant disease epidemics (Kranz and Royle, 1978; Sutherst, 1993; Xu, 2006).

II. METHODOLOGY

2.1 In-vivo test:

Field trial was carried out in the experimental plot of Department of Plant Pathology, Allahabad School of Agriculture, SHUATS, Allahabad, U.P., in a consecutive two cropping seasons of Kharif (2014-15) and (2015-16) by using a susceptible Manipur paddy cultivar *viz.*, Daramphou. Field layout were made in Randomized Block Design (RBD) with plot size (2x3) sq. m., a 25 days old seedlings were transplanted with spacing 20 cm (row x row) and 15 cm (plant x plant), with 2-3 seedlings/hill.

2.2 Development of model for weather based prediction system for brown spot disease of rice:

Agrometeorological data was collected from automatic weather station of the Sam Higginbottom University of Agricultural, Technology and Sciences (SHUATS), Allahabad, (U.P.), Central India. Weather factors such as temperature maximum (Tmax.), minimum temperature (Tmin.), Average temperature (Tavge), maximum relative humidity (RHmax.), minimum relative humidity (RHmin.), rainfall (RF) and wind speed (WS) were the parameters taken into consideration for epidemic studies during the period of investigation. The summary of the weather data taken during the period of investigation are presented on following Table 1.

TABLE 1
AGROMATEOROLOGICAL OBSERVATION DURING DISEASE SEVERITY AND EPIDEMIOLOGY STUDIES (2014-15) and (2015-16)

Month	Week	Mean temperature (0^0C)				Relative humidity (%)				Rainfall (mm/hr.)		Wind speed (Km/hr.)	
		2014		2015		2014		2015		2014	2015	2014	2015
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.				
Sept.	4th	36.34	26.71	36.25	27.8	85.5	48.14	90	47.14	0	0.7	1.46	1.73
Sept.	5th	37.6	25.5	36.2	27.8	86	42.5	88.5	53.5	0	0	2.39	1.68
Oct.	1st	35.22	25.02	35.94	27.88	87	47.84	90	48.71	0	0	2.18	1.42
Oct.	2nd	34.65	24.51	35.94	26.71	85.28	60.85	91.57	53.28	109.6	0	1.47	1.31
Oct.	3rd	44.8	28.56	35.28	22.17	78.8	28.8	92.14	50.85	0	0	19.5	0.78
Oct.	4th	32.31	20.22	36.4	20	86.57	54.28	92.42	41.12	0	0	0.57	0.68
Oct.	5th	33.2	20.53	34.93	19.33	85.66	51.66	91.66	52.66	0	4.5	0.55	0.60

Source: Agrometeorological station, SHUATS, Naini, Allahabad, U.P. east, central India.

2.3 Mathematical modelling of cause of epidemic:

2.3.1 Correlation studies:

Correlation measures the degree of association between variables of equal status. There need to be no concept of cause and effect. For calculation of correlation of both dependent and independent variables need to be normally distributed where as for regression this is necessary only for the dependent variables.

2.3.2 Multiple regression analysis studies:

Disease severity variable is being considered as dependable variable and independable variables as weather parameters such as maximum temperature (Tmax.), minimum temperature (Tmin.), Average temperature (Tavge.), maximum relative humidity (Rhmax.), minimum relative humidity (Rhmin.), rainfall (RF) and wind speed (WS) etc. Then stepwise regression equation is used and to obtained desirable results to describe the relationship between dependent and independent variables. The disease severity is called the dependent (response) variable Y and is said to regress on the weather parameters are called the independent (determining) variables X. The application of multiple regression analysis is to join observations of disease data as dependent variable and independent variables on disease development to estimate the change in disease severity which can be expected from a unit change in these variables and also find out the key factors as predictor for the prediction of the disease severity. For study of the multiple effects on dependent variables, the multiple regression analysis (MRA) was done as a predictive equation. The prediction models and stepwise multiple regression analysis was done by using the following equation.

$$\acute{Y} = b_0 + b_1x_1 + b_2x_2 \ldots\ldots\ldots\ldots b_nx_n \quad (1)$$

Where,

$\acute{Y}$ = predicted disease severity

b_0 = intercept

$b_1b_2 \ldots\ldots\ldots\ldots b_n$= regression co-efficient

$x_1x_2 \ldots\ldots\ldots\ldots X_n$ = independent variable

In this equation the regression coefficients (or B coefficients) represent the independent contributions of each independent variable to the prediction of the dependent variable. Another way to express this fact is to say that for example variable X_1 is correlated with the Y variable, after controlling for all other independent variables. SPSS software (SPSS Inc., Chicago,IL) was used to perform multiple regression analysis to develop the disease prediction models where brown spot severity was used as the dependent variable and 10 days average of various weather variable 9 days prior to disease assessment *viz.* max. temp. (X_1), min. temp.(X_2), max. Rh (X_3), mini. Rh.(X_4), rainfall(X_5), Wind speed (X_6) were used as independent variable.

(Machine learning techniques in disease forecasting: a case study on rice bl https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1647291/14 of 22 8/8/2010 7:52 PM)

- **Correlation studies of brown spot of rice with weather factors along with different treatment.**

TABLE 2
CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER PROPICONAZOLE TRIAL (2014-15)

Propiconazole	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.86	-.96	.61	.83	.93	-.33
Tmax	-.86	1	.91	-.56	-.41	-.84	.55
Tmin	-.96	.91	1	-.42	-.69	-.83	.58
RF	.61	-.56	-.42	1	.46	.85	.39
RHmax	.82	-.41	-.69	.46	1	.72	.02
RHmin	.93	-.84	-.83	.85	.72	1	-.07
WS	-.33	.55	.58	.39	.02	-.07	1

Correlation is significant at the 0.05% level

TABLE 3
CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER MYCLOBUTANIL TRIAL (2014-15)

Myclobutanil	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.96*	-.99*	.55	.66	.90	-.49
Tmax	-0.96*	1	.91	-.56	-.41	-.84	.55
Tmin	-0.97*	-.99	.91	1	-.42	-.69	-.83
RF	0.55	.55	-.56	-.42	1	.46	.85
RHmax	0.66	-.41	-.69	.46	1	.72	.02
RHmin	0.89	-.84	-.83	.85	.72	1	-.068
WS	-0.49	-.49	.55	.58	.39	.02	-.068

Correlation is significant at the 0.05% level

TABLE 4
CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER PROPINEB TRIAL (2014-15)

Propineb	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.89	-.95*	.67	.78	.96*	-.31
Tmax	-.89	1	.91	-.56	-.41	-.84	.55
Tmin	-.95*	.91	1	-.420	-.69	-.83	.57
RF	.67	-.56	-.42	1	.46	.85	.391
RHmax	.78	-.41	-.69	.46	1	.72	.022
RHmin	.96*	-.84	-.83	.85	.72	1	-.06
WS	-.31	.55	.58	.39	.02	-.06	1

****Correlation is significant at the 0.05% level***

TABLE 5
CORRELATION STUDIES OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER CARBENDAZIM TRIAL (2014-15)

Carbendazim	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.974	-.889	.721	.513	.935	-.353
Tmax	-.975	1	.912	-.555	-.414	-.840	.549
Tmin	-.889	.912	1	-.420	-.694	-.831	.579
RF	.721	-.555	-.420	1	.461	.851	.391
RHmax	.513	-.414	-.694	.461	1	.722	.022
RHmin	.935	-.840	-.831	.851	.722	1	-.068
WS	-.353	.549	.579	.391	.022	-.068	1

****Correlation is significant at the 0.05% level***

TABLE 6
CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER THIOPHANATE TRIAL (2014-15)

Thiophonate	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.98*	-.93	.37	.38	.72	-.71
Tmax	-.98	1	.91	-.56	-.41	-.84	.55
Tmin	-.93	.91	1	-.42	-.69	-.83	.58
RF	.37	-.56	-.42	1	.46	.85	.392
RHmax	.38	-.41	-.69	.46	1	.72	-.07
RHmin	.74	-.84	-.83	.85	.72	1	1
WS	-.71	.55	.58	.39	-.07	-.71	1

****Correlation is significant at the 0.05% level***

TABLE 7
CORRELATION STUDY OF BROWN SPOT DISEASE OF RICE WITH WEATHER FACTORS UNDER CONTROL TRIAL (2014-15).

Control	DS	Tmax	Tmin	RF	RHmax	RHmin	WS
DS	1	-.98*	-.93	.37	.38	.74	-.71
Tmax	-.98*	1	.91	-.56	-.41	-.84	.55
Tmin	-.93	.91	1	-.42	-.69	-.83	.58
RF	.37	-.56	-.42	1	.46	.85	.39
RHmax	.38	-.41	-.69	.46	1	.72	.02
RHmin	.74	-.84	-.83	.85	.72	1	-.07
WS	-.71	.55	.58	.39	.02	-.07	1

****Correlation is significant at the 0.05% level***

From the data presented in the above Table (2),(3), (4), (5), (6) and (7) revealed that during first year of studies (2014-15), brown spot incidence was significant and negatively correlated with Tmax (r = -.98*), Tmin (r= -.93) and WS (r=-.71) whereas, RHmax (r=0.38) and RHmin (r=0.74) and rainfall (RF = 0.37) which is non significant and positively correlated to brown spot disease severity. Thus, from the present finding, it may be concluded that temperature (Tmax), temperature (Tmin) and Wind speed (WS) are three important weather factors that significantly influenced the severity of brown spot disease of rice. The present findings also supported that as temperature significantly influences the disease progression of brown leaf spot of rice (Dasgupta and Chattopadhyay, 1977). Agrometeorological observation recorded during the studies (Table 1) also supported as reported weather temperature 24°C to 30°C are favourable conditions for disease development (Picco and Rodofil, 2002). Some researchers observed that brown spot incidence is generally not influence with regular rainfall in years (Singh *et al.* 2005). Similarly, in case of our present investigation brown leaf spot disease incidence was found not influenced by rainfall weather factor as shown in the above results data in the years of studies.

- **Development of Prediction Model based on Stepwise Regression Analysis:**

TABLE 8
PREDICTION MODEL/EQUATION FOR BROWN SPOT DISEASE OF RICE BASED ON STEPWISE MULTIPLE REGRESSION ANALYSIS DURING CROP SEASON (2014-15) IN CONTROL PLOT

Sl. No.	Model	R^2	Adjusted R^2
1.	Y= 276.987-7.520*(Tmax)	0.68	0.59
2.	Y= 1559.690-9.407*(Tmax) -14.113*(RHmax)	0 .97	0.96
3.	Y=1669.356-10.635*(Tmax)-14.559*(RHmax)-.575*(RHmin)	0.99	0.99

TABLE 9
PREDICTION MODEL FOR BROWN SPOT DISEASE OF RICE BASED ON STEPWISE MULTIPLE REGRESSION ANALYSIS FOR SELECTED FUNGICIDES TREATMENT DURING CROP SEASON (2014-15)

Sl. No.	Fungicide	Model	R^2	Adjusted R^2
1.	Propiconazole	Y=360.741-13.694(Tmax)	.95	.93
2.	Thiophonate	Y=77.693-2.27(Tmin)	.92	.88
3.	Myclobutanil	Y=82.947-2.256.694(Tmin)	.97	.95
4.	Carbendazim	Y=140.707-5.312(Tmax)	.95	.91

Multiple Regression Analysis based prediction model was most commonly developed for predicting disease incidence. But it is wise to go Stepwise Regression technique in order to determine the contribution of individual variables in brown spot disease prediction model during two years of studies (Table 8 & 9). The weather variables i.e., temperature (Tmax.) and (Tmin.), Relative humidity (RH), and rainfall (RF) had shown significant influence in the disease development. Since, weather factors influence the biology of the pathogen. The key weather variables *viz.*, Maximum temperature, Minimum temperature had shown influencing disease development during the study through Stepwise Regression analysis model. The weather factors contributed 68 to 97 per cent variability in disease development.

Combine weather parameters effect of temperature (Tmax.) and Relative humidity (Rhmin.) was found contributing in disease development with coefficient determination value 0.97%. Similarly Tmax, Rhmin and Rhmax were also found influencing on brown spot disease incidence as indicated by the coefficient determination value (R^2) 0.99%.

Multiple Regression Analysis (MRA) was used when disease severity was taken as dependent factors and weather factors *viz.*, maximum temperature (Tmax.) and minimum temperature (Tmin.), rainfall (RF) and wind speed (WS) determine the effect of an independent factors (weather data) collected from the agrometeorology department for finding disease development (Table 1). The stepwise regression technique was used to obtain prediction model based on significant of coefficient determination value (R^2). However, the weather factors as predictors was undertaken to explain key factor which influences disease incidence. Multiple Regression Analysis Stepwise equation showed that maximum temperature was found to be an important factor for brown spot disease development during (2014-15), which is supported by highly significant coefficient value of determination. The R^2 value was 0.96 suggesting that the model is fitted well. Thus, the model was good for predicting brown spot disease incidence. It means that model could give only 95.6% prediction. The standard error of estimate was also very low. Only two parameters, minimum temperature and maximum temperature contributed towards the development of predictive model. A multiple regression model has been developed based on study of epidemic of leaf blight in relation to various agrometeorological weather factors (Chattopadhay *et al*. 2005; Singh *et al*. 2008; Sangeetha and Siddharamaiah, 2007). Predictive model was proposed by previous researchers on airborne inoculums subjected as an important variable in model of *Ascochyta blight* (Schoeny *et al*. 2007).

III. CONCLUSION

The correlation studies of disease incidence and the weather factors found that conducive temperature range i.e. minimum (Tmin.) and maximum (Tmax.) influences disease severity was at 20.22ºC-44.8ºC ranges as indicated by the weather factor (temperature) during the years of studies (2014-15). The Multiple regression analysis found maximum temperature was the key weather factors for brown spot disease severity and is also the important predictors in the treatment application that explain the variation for more than 95% during the year of its investigation, 2014-15.

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