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Effect of environmental factors on rust disease severity and rate of spread of bach (*Acorus calamus* L.) in West Bengal, India

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Abstract

Bach (*Acorus calamus* L.) is an important medicinal plant found predominantly in the Himalayan and sub-Himalayan regions of India, generally known to cure several diseases like fever, asthma, and bronchitis (Reddy *et al.*, 2018). Like other crops, bach is also affected by several biotic and abiotic factors leading to a decline in the yield, out of which rust disease caused by *Uromyces spp* is one of the major biotic factors. The effect of weather factors like temperature, relative humidity, rainfall and bright sunshine hours on the incidence and development of rust disease was studied under field condition in West Bengal, to correlate the rust disease severity with weather parameters. Stepwise multiple regression analyses for prediction of the rust disease severity of bach revealed that maximum temperature exhibited highly significant positive contribution on the Percent Disease Index (PDI) increment and was identified as critical while the minimum temperature exhibited highly significant contribution on the rate of spread (ROS) and was identified as critical. Comparison of weather parameters with the rate of spread of disease revealed that the range of maximum temperature 23-26 °C, minimum temperature 8-10 °C, maximum relative humidity 93-97%, minimum relative humidity-50-68%, followed by low rainfall and bright sunshine hour of 8-9 hours were suitable for higher rate of disease spread.

Keywords: Medicinal plant, bach, *Acorus calamus*, *Uromyces spp*, rust, correlation

Introduction

Bach, *Acorus calamus* Linn. (Acoraceae), also known as sweet flag is a perennial, fragrant medicinal herb that is used to treat a wide range of health ailments, including neurological, gastrointestinal, respiratory diseases, kidney, and liver disorders. Bach is also useful in curing of fever, appetite loss, bronchitis, chest pain, colic, cramps, diarrhoea, digestive disorders (Sarkar, 2013) [9]. Like any other crops, medicinal plants also have several biotic and abiotic factors that limit the production of these crops. The pathogenic disease cause significant damage of the crops as well as reduce the quality of the produces and acceptability to the market. It may reduce the active chemicals components in the plant parts used for medicinal purpose (Mukherjee, 2009) [3]. Rust disease is one of the devastating diseases of *Acorus calamus* L. which was reported by Ramakrishnan and Rangaswami (1948) [7] for the first time and its causal organism was named as *Uromyces acori*. Nirmalkar and Lakpale (2008b) [4] also made an extensive study for symptomatology, taxonomy and morphological behavior of uredospores of *Uromyces acori* collected from different localities in Chhattisgarh region of India and observed the symptoms as reddish brown pustules on both surface of leaves with ruptured epidermis. Rust disease epidemic or severity can occur in varied levels in the field with the change in host varieties, pathogen forms, the amount of inoculum present and weather parameters during the growth season. If the host is susceptible and rust pathogen is virulent, then the weather parameters individually or collectively may regulate the disease, its direction and intensity of epidemics. Correlation of weather variables with disease severity and rate of spread of disease(s) has not been attempted. No attempts have been made to identify the critical weather parameters for disease severity increment or to develop any model for prediction of disease severity against the damaging diseases of these medicinal plants. Keeping the above research gap in mind, the present study on bach plant was undertaken with to identify weather variable (s) responsible for disease severity and rate of disease spread.

Materials and Methods

Fixed plot survey, disease scoring scale and preparation of disease scoring card

For fixed plot survey rust disease of Bach caused by *Uromyces acori*, were selected. The survey was conducted on monthly interval starting from the month of December, 2013 to April, 2014 at the medicinal plants garden situated at the medicinal and aromatic plants garden, BCKV, Mohanpur, Nadia district, West Bengal. Meteorological data on daily maximum and minimum temperature, maximum and minimum relative humidity, rainfall and bright sunshine hours (B.S.H) were collected during January to April 2014 from the record of Department of Agricultural Meteorology and Physics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal. Later on, all these meteorological data were averaged over 7 days. The incidence and severity of the diseases which appeared on the medicinal plants were recorded. Ten plants were selected in every plot. For percent disease incidence total no. of leaves/stems infected in a plot were recorded. Rust disease severity on leaves were recorded based on 0-8 scale (Table 1).

Disease on affected leaves was scores using such scale and percent disease index (PDI) was calculated following the formula given by McKinny (1923) [2].

$$\text{PDI} = \frac{\text{Sum of individual disease rating}}{\text{Number of observations} \times \text{Maximum disease grade}} \times 100$$

Percent disease incidence was calculated from the following formula:

$$\text{Percent disease incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plants}} \times 100$$

Table 1: Detailed descriptions 0-8 scale used for scoring bach rust disease

Scale	Description
0	No infection or 0% infection
1	1-2.5% leaf area covered by disease
2	2.6-5% leaf area covered by disease
3	6-10% leaf area covered by disease
4	11-20% leaf area covered by disease
5	21-40% leaf area covered by disease
6	41-60% leaf area covered by disease
7	61-80% leaf area covered by disease
8	81-100% leaf area covered by disease

Disease development in relation to environmental factors

Percent Disease Index (PDI) of the disease was scored at seven days interval and weekly average of the different meteorological variables was worked out. Natural incidence and epiphytotic development of the rust disease in field was permitted during the entire period of experimentation. Simple correlation coefficients amongst any pair of the variables like maximum temperature (x_1), minimum temperature (x_2), maximum relative humidity (x_3), minimum relative humidity (x_4), rainfall (x_5), bright sunshine hour (x_6) and PDI (Y) were worked out and arranged in the form of a matrix.

Multiple regression analysis for prediction of disease severity was done using the equation-

$$Y = b_0 + b_1X_1 + b_2X_2 + \dots + b_nX_n \text{ where}$$

Y = predicted disease severity,

b_0 = intercept,

$b_1, b_2, b_3, \dots, b_n$ = regression coefficients and

$X_1, X_2, X_3, \dots, X_n$ = independent variables.

But stepwise multiple regression analysis was done to find out the most critical weather parameter(s) contributing much towards the disease severity.

PDI data recorded at seven days interval were used to find out the rate of spread (r) of disease as per the formula proposed by Vander Plank (1963) [11].

$$\text{Rate of spread (r)} = \frac{1}{T_2 - T_1} \log_e \frac{X_2}{1 - X_2} - \log_e \frac{X_1}{1 - X_1}$$

Where,

$T_2 - T_1$ = time interval between two observations,

X_1 = percent disease index at T_1 and

X_2 = percent disease index at T_2 .

Results and Discussion

Disease scoring card development for the assessment of Bach rust disease severity

For the assessment of Bach rust disease severity, a disease scoring card was prepared which could be used as reference card during the scoring of this disease (Plate 1) under field condition. The area of disease affected part and the total area of leaf i.e., healthy as well as affected areas of the leaves were measured and finally percent area of the affected part was worked out. percent of leaf area affected and its corresponding PDI scale with definite range of percent value was being indicated in plate 1. An accurate assessment of disease developed in a field crop is of great importance in Plant Pathology, particularly from epidemiological point of view and relating this to loss in yield still remains one of its difficult problems (Sinha, 2004) [10]. Under or over estimation of disease severity may cause problems in resorting of control measures that may lead to considerable expenditure. So, assessment of disease should be made accurately. Development of disease scoring card has the immense utility for accurate assessment of disease developed in a field crop and it helps to those workers who are engaged in disease severity and crop loss assessment. The card can be used as reference for easy, rapid and accurate assessment of disease severity. Disease scoring card with definite scale has been developed earlier by various workers in different crops and their diseases. Park (1978) [5] used 1-5 scales for assessing mungbean Cercospora leaf spot disease severity, Parry (1990) [6] also used 1-5 scales for scoring of powdery mildew disease severity and Khare *et al.* (1993) [11] used 0-9 scales for measuring of lentil rust disease severity.

Bach rust disease severity prediction in relation to meteorological parameters

Variations in plant disease severity occur because of change in host varieties, pathogen forms, the amount of inoculum present and weather parameters during the growth season. If the host is susceptible and pathogen is virulent, then the weather parameters individually or collectively may regulate the course, direction and intensity of epidemics. Plant Pathologists still put their concerted efforts to develop

mathematical models for prediction of disease severity of some common and damaging diseases. Rust disease is one of the damaging diseases of bach. Attempts were made in the present experiment to correlate the rust disease severity with weather parameters and to identify the critical weather parameters contributing much towards the increment of

disease severity. Mean of six weather parameters (taken on 10 dates of observations averaged over seven days) like maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, rainfall and bright sunshine hour along with the PDI of rust disease were recorded and presented (Table 2).

Table 2: Average value of different weather parameters, PDI and rate of spread of rust disease of bach at different dates of observation.

Dates	Maximum Temp. (°C)	Minimum Temp. (°C)	Total Rainfall (mm)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)	BSH (Bright sunshine hours)	PDI* value of rust	Rate of spread of disease
29-Jan-14	24.3	10.6	0	93.3	61.3	8.5	0	-
05-Feb-14	24.9	9.3	0	95.9	50.9	8.3	5.4	0.300
12-Feb-14	29	14.4	0	95.9	46.8	8.6	10.4	0.101
19-Feb-14	24.9	14.2	2.8	95.6	59	6.8	16.1	0.071
26-Feb-14	27.6	13.8	0	96.3	53.9	8.8	31.4	0.124
05-Mar-14	28.7	16.4	0	94.9	58.6	7.5	49.3	0.108
12-Mar-14	30.4	15.8	0	90.9	49.3	9.5	62.5	0.077
19-Mar-14	34	18	0	87.3	48	9.4	73.9	0.076
26-Mar-14	33	19.4	3.5	93.6	49.4	8.4	81.1	0.059
02-Apr-14	36.4	23	0	92.4	40.7	9.4	88.2	0.079

*Mean of all leaves of seven plants, PDI= Percent Disease Index

From the Table-2, simple correlation coefficients were worked out amongst any pair of the variables like maximum temperature (x1), minimum temperature (x2), maximum relative humidity (x3), minimum relative humidity (x4), rainfall (x5), bright sunshine hour (x6) and PDI (YPDI). Finally, simple correlation coefficients were arranged in the form of a matrix (Table 3). It was evident from the Table 3 that maximum temperature and minimum temperature were highly significant and positively correlated whereas maximum and minimum relative humidity were significant and negatively correlated with the PDI.

Stepwise multiple regression analyses were also performed using PDI (as dependent) and maximum temperature (x1), minimum temperature (x2), maximum relative humidity (x3), minimum relative humidity (x4), rainfall (x5) bright sunshine hour (x6) as independent variable for the identification of critical weather parameter(s) contributing much towards PDI increment. Results of the stepwise multiple regression analyses for prediction of the rust disease severity of bach and its coefficients of multiple determination (R²) value revealed that a combined effect of maximum temperature and minimum relative humidity explained 91.1% of the total variation of PDI accounted for (Table 4). Out of these two parameters maximum temperature exhibited highly significant contribution in explaining the variation whereas the contribution of minimum relative humidity remained insignificant. So the contribution of maximum temperature on the PDI increment has been identified as critical. The representative multiple

regression equation for prediction of rust disease severity of bach was $YPDI5^{**} = -352.264 + 9.917x1^{**} + 1.995x4$ (where coefficients of multiple determination R² = 0.911, adjusted coefficients of multiple determination R² = 0.886, multiple regression R = 0.955 and standard error of estimate = 11.269).

Table 3: Correlation matrix amongst percent disease index of rust disease and meteorological parameters.

	x1	x2	x3	x4	x5	x6	Y
x1	1.000						
x2	0.929	1.000					
x3	-0.612	-0.456	1.000				
x4	-0.795	-0.624	0.347	1.000			
x5	0.010	0.207	0.162	0.153	1.000		
x6	0.616	0.347	-0.620	-0.695	-0.505	1.000	
Y	0.926**	0.915**	-0.619*	-0.596*	0.163	0.482	1.000

x1 = Maximum temperature, x2 = Minimum temperature, x3 = Maximum relative humidity, x4 = Minimum relative humidity, x5 = Rainfall, x6 = Bright sunshine hour and Y = PDI

Based on PDI value of rust disease and the time interval between any two dates of observations, rate of spread (ROS) of the disease was worked out (Table 2). Finally, simple correlation coefficients were worked out and were arranged in the form of a matrix (Table 5). It was evident from the table that minimum temperature was highly significant and negatively correlated with the rate of spread of disease.

Table 4: Step down multiple regression equations for prediction of rust disease severity on bach

Step nos.	Regression equations	COMD R ²	Adj. R ²	Multi R	SEOE
1.	$Y_{PDI1} = -320.820 + 7.981x_1 + 1.053x_2 - 0.243x_3 + 1.783x_4 + 3.471x_5 + 4.758x_6$	0.924	0.772	0.961	15.932
2.	$Y_{PDI2} = -358.390 + 8.339x_1 + 0.860x_2 + 1.879x_4 + 3.515x_5 + 5.033x_6$	0.924	0.829	0.961	13.809
3.	$Y_{PDI3}^{**} = -368.538 + 9.365x_1^{**} + 1.952x_4 + 3.570x_5 + 3.809x_6$	0.923	0.862	0.961	12.394
4.	$Y_{PDI4}^{**} = -333.731 + 9.631x_1^{**} + 1.769x_4 + 2.458x_5$	0.920	0.881	0.959	11.536
5.	$Y_{PDI5}^{**} = -352.264 + 9.917x_1^{**} + 1.995x_4$	0.911	0.886	0.955	11.269

COMD R² = Coefficient of multiple determination; Adj. R² = Adjusted R²; Multi R = Multiple correlation; SEOE= Standard error of estimate

Stepwise multiple regression analyses were also performed using ROS (as dependent) and maximum temperature (x_1), minimum temperature (x_2), maximum relative humidity (x_3), minimum relative humidity (x_4), rainfall (x_5) bright sunshine hour (x_6) as independent variables for the identification of critical weather parameter(s) contributing much towards ROS. Results of the stepwise multiple regression analyses for prediction of the rust disease severity of bach and its coefficients of multiple determination (R^2) value revealed that a combined effect of minimum temperature and minimum relative humidity explained 65.1% of the total variation of ROS accounted for (Table 6). Out of these two parameters minimum temperature exhibited highly significant contribution in explaining the variation whereas the contribution of minimum relative humidity remained insignificant. So, the contribution of minimum temperature on the ROS has been identified as critical. The representative multiple regression equation for prediction of rate of spread of rust disease was $Y_{ROS5}^* =$

$0.660 - 0.018x_2^{**} - 0.005x_4$ (where coefficients of multiple determination $R^2 = 0.651$, adjusted coefficients of multiple determination $R^2 = 0.534$, multiple regression $R = 0.807$ and standard error of estimate = 0.050).

Table 5: Correlation matrix on rate of spread of bach rust disease and meteorological parameters

	x_1	x_2	x_3	x_4	x_5	x_6	Y
x_1	1.000						
x_2	+ 0.914	1.000					
x_3	-0.695	-0.522	1.000				
x_4	-0.743	-0.521	0.431	1.000			
x_5	-0.063	0.153	0.158	0.285	1.000		
x_6	+ 0.677	0.379	-0.620	-0.810	-0.514	1.000	
Y	-0.550	-0.729**	0.402	-0.086	-0.352	-0.098	1.000

x_1 = Maximum temperature, x_2 = Minimum temperature, x_3 = Maximum relative humidity, x_4 = Minimum relative humidity, x_5 = Rainfall, x_6 = Bright sunshine hour and Y = Rate of Spread

Table 6: Step down multiple regression equations for prediction of rate of spread of bach rust disease.

Step Nos.	Regression equations	COMD R^2	Adj. R^2	Multi R^2	SEOE
1.	$Y_{ROS1} = -0.059 + 0.027x_1 - 0.035x_2 + 0.006x_3 - 0.004x_4 - 0.013x_5 - 0.051x_6$	0.751	0.005	0.867	0.074
2.	$Y_{ROS2} = 0.888 + 0.018x_1 - 0.030x_2 - 0.006x_4 - 0.014x_5 - 0.057x_6$	0.732	0.285	0.855	0.063
3.	$Y_{ROS3} = 1.051 - 0.016x_2^{**} - 0.008x_4 - 0.013x_5 - 0.032x_6$	0.701	0.402	0.837	0.057
4.	$Y_{ROS4} = 0.912 - 0.018x_2^{**} - 0.007x_4 - 0.016x_6$	0.664	0.463	0.815	0.054
5.	$Y_{ROS5}^* = 0.660 - 0.018x_2^{**} - 0.005x_4$	0.651	0.534	0.807	0.050

COMD R^2 = Coefficient of multiple determination; Adj. R^2 = Adjusted R^2 ; Multi R = Multiple correlation; SEOE = Standard error of estimate



Plate 1: Disease scoring card with scale denoted in Parentheses and percent area affected by rust disease of Bach.

In the present experiment, PDI was found to increase from 0.0% up to 88% whereas rate of spread of disease for the corresponding period exhibited erratic pattern. When the effect of six weather parameters viz. maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, rainfall and bright sunshine hour on PDI increment and rate of spread was studied, the contributions of maximum temperature on the PDI increment and minimum temperature on rate of spread of

disease were identified as critical. Maximum temperature and minimum had highly significant positive and negative contribution on the PDI increment and rate of spread of bach rust disease respectively. Comparison of weather parameters like maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, rainfall and bright sunshine hour with the rate of spread of disease revealed that the ranges of maximum temperature 23-26 °C, minimum temperature 8-10 °C, maximum relative

humidity 93-97%, minimum relative humidity-50-68%, followed by low rainfall and bright sunshine hour of 8-9 hours were suitable for higher rate of disease spread (Figure 6). The level of disease severity and its change in pattern in the rate of spread of disease showed much similarity with the findings of Nirmalkar and Lakpale (2008b) ^[4] wherein they conducted an experiment to study and determine the most favorable period of disease progress in sweet flag (*Acorus calamus*) from April 2005 to March 2006. They recorded disease progress at 15-days intervals by randomly selecting 10 leaves to calculate the disease severity. The results revealed an erratic trend in the increase or decrease of rust disease severity from the first fortnight of April to the first fortnight of July. Disease severity gradually increased from the second fortnight of July and continued until the second fortnight of December (2.8-88.1%) where it reached its maximum level. Thereafter, gradual decline in disease severity was observed (66.80 to 42.50%). In the initial stages of disease development, apparent infection rate was increased rapidly and thereafter it declined.

Conclusion

The present study demonstrated that development of a disease scoring card is highly useful for accurate, easy, and rapid assessment of bach rust disease severity under field conditions. The card ensures precise estimation of disease intensity, avoiding under or over assessment that may otherwise affect control measures. Correlation and regression analyses revealed that maximum temperature significantly influenced PDI increment, while minimum temperature critically affected the rate of spread of rust disease. Favorable ranges of temperature, relative humidity, rainfall, and sunshine hours were identified for higher disease progression. Thus, maximum and minimum temperatures emerged as key meteorological determinants for predicting rust disease severity and spread in bach, aiding in timely management strategies.

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