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Prediction of intensity and rate of spread of Chrysanthemum leaf blotch disease (*Septoria chrysanthemella* Sacc.) in relation to weather parameters

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Per cent disease index (PDI) and rate of spread of Chrysanthemum leaf blotch disease worked out as dependent variables were attempted to correlate with the five common independent weather variables *e.g.* maximum temperature (x_1), minimum temperature (x_2), maximum relative humidity (x_3), minimum relative humidity (x_4) and rainfall (x_5). Attempt was also made to find out critical and contributory weather variables for each dependent variable. Simple correlation studies of PDI and rate of spread of disease with weather variables revealed that maximum (r = 0.753*) and minimum relative humidity (r = 0.832) and minimum temperature (r = 0.664*) were positively and significantly correlated with PDI whereas minimum temperature was the only weather variable which exhibited negative and significant correlation (r = - 0.671*) with the rate of spread of disease. Following the multiple regression analyses by backward method, a best fitted multiple regression equation out of four equations *i.e.* $Y_{PDI4}^{**} = -750.790 + 12.900x_1^{**} + 5.114x_4^{**}$ was developed for the prediction of Chrysanthemum leaf blotch disease intensity. It was evident from the regression equation that the enhancement of maximum temperature and minimum relative humidity had significant positive contribution towards the PDI increment. Following the same method of regression analysis, another representative and best fitting multiple regression equation out of three *i.e.* $Y_{ROS3}^{**} = 5.657 - 0.211x_1^{**} + 0.172x_2^{**} - 0.0.037\, x_4^{**}$ was worked out for the prediction of rate of spread (ROS) of disease. From this regression equation it was cleared that the increment of maximum temperature and minimum relative humidity had significant negative and augmentation of minimum temperature had significant positive contribution towards the increment of rate of spread of disease.

Key words: Chrysanthemum, PDI, prediction, rate of spread, *Septoria,* weather

INTRODUCTION

Leaf blotch disease (c.o. *Septoria chrysanthemella* Sacc.) is regarded as the most serious, economically important, wide spread and destructive foliar disease of chrysanthemum. It was reported first by Sydow and Butler in 1916 from Dehradun and is now known to be distributed in all chrysanthemum growing areas throughout the India (Pavgi and Upadhyaya, 1966; Rangaswamy *et al.*, 1970; Patil and Rao, 1973; Sahni, 1980; Khara and Kaur, 1983). It was also reported from UK by Punithalingam (1967). The growth and yield potential of crop is drastically reduced due to the damage in number and areas of the functional leaves by this disease. The intensity of disease has been reported to vary from 1 to 90 %, depending on genotypes, positions of leaves on the same plant (De, 2013) and environmental parameters (Chandel and Chandel, 2010). Besides disease intensity, rate of spread of disease may also be influenced by the environmental parameters. The knowledge about intensity and rate of spread of disease is of paramount importance because it determines not only the quantum of disease but also measures the rapidity of disease progress. This exercise is considered critical to identify the time when suitable disease control measures are needed to be taken up. Information on pattern of progress of disease intensity and rate of spread of disease as influenced by environmental parameters are extremely lacking at the study location. Even the information generated in/outside the country on this aspect has not been validated for its suitability under study location. Keeping the above significances in mind, a study has been conducted (i) to establish relationship among common weather variables with the intensity and rate of spread of the disease (ii) to identify critical weather parameters contributing much towards intensity and rate of spread of the disease and (iii) to develop suitable regression equation for the prediction of disease intensity and rate of spread of the disease.

MATERIALS AND METHODS

A field experiment was conducted on alluvial soil at the Horticultural Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Mondouri (22°43' N latitude and 88°34' E longitude with an elevation of 9.75 m above mean sea level), Nadia under State of West Bengal, India. Leaf blotch disease susceptible chrysanthemum cultivar, BC- 35, was selected, planted with a spacing of 50 cm x 50 cm and grown in a plot size of 2 m x 2 m in triplicate following recommended practices for this study. One twig /plant and three plants /replication were randomly selected. A total of nine plants were finally considered from three replications. A particular portion of each twig with 15 – 17 leaves and zero PDI was marked with tags at the onset of data recording. All the healthy and diseased leaves of the marked area of nine twigs were scored at seven days interval using 0 - 6 scale [0 = 0% leaf area covered by disease (immune), 1 = 1-5% leaf area covered (highly resistant), 2 = 6 - 10% leaf area covered (resistant), 3 = 11-25% leaf area covered (moderately resistant), 4 = 26-50% leaf area covered (moderately susceptible), 5 = 51-75% leaf area covered (susceptible) and 6 = 76-100% leaf area covered (highly susceptible)]. After scoring the per cent area of leaf affected by leaf blotch disease, PDI (Per cent Disease Index) was calculated following standard formula given by McKinny (1923).

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

Natural incidence and epiphytotic development of the leaf blotch disease in field was permitted during the entire period of experimentation.

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 Van der Plank (1963)

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

where, $T_2 - T_1$ = time interval between two observations, X_1 = per cent disease index at T_1 and X_2 = per cent disease index at T_2.

The weather parameters like temperature (maximum and minimum), relative humidity percentage (maximum and minimum) and rainfall (mm) on the incidence and development of Chrysanthemum leaf blotch disease were recorded from the nearby meteorological station of the University during the entire period of experimentation and weekly averages of the different meteorological variables were worked out. Simple correlation coefficients amongst any pair of the weather variables like maximum temperature (x_1), minimum temperature (x_2), maximum relative humidity (x_3), minimum relative humidity (x_4) and rainfall (x_5) and PDI (Y_{DI}) and rate of spread (Y_{ROS}) of disease were worked out and arranged in the form of matrix separately for PDI and rate of spread. Multiple regression analysis for prediction of disease severity was done using the equation- $Y = a + b_1X_1 + b_2X_2$ —— b_nX_n where Y = predicted disease severity or rate of spread of disease, a = intercept, b_1, b_2, b_3 —— b_n = partial regression coefficients and X_1, X_2, X_3 —— X_n = independent variables. Multiple regression analysis was done following backward method to find out the most critical weather parameter(s) contributing much towards the disease intensity increment and influencing greatly to the rate of spread of disease. All data were statistically analyzed using SPSS software version 19.

RESULTS AND DISCUSSION

The PDI, rate of spread of leaf blotch disease and mean weather parameters like maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and rainfall at

Table 1 : PDI, rate of spread of Chrysanthemum leaf blotch disease and average of weather parameters at different dates of observation

Dates of observation	Max. Tem. (^{0}C)	Min. Tem. (^{0}C)	Max. RH (%)	Min. RH (%)	Rainfall (mm)	PDI of leaf blotch	Rate of spread of leaf blotch
05-5-2012	34.9	22.9	87.2	60.0	18.9	0.0	0.0
12-05-2012	35.3	24.4	89.6	58.0	0	5.16*	0.273
20-05-2012	37.5	27.3	87.9	59.5	0	28.19	0.247
26-05-2012	37.2	27.4	90.7	63.2	2.9	56.47	0.199
02-06-2012	36.6	27.9	92.1	71.4	0	73.05	0.105
09-06-2012	38.4	28.8	89.9	66.0	0	83.09	0.085
16-06-2012	36.1	27.1	89.7	70.3	3.8	91.22	0.107
23-06-2012	32.5	26.1	95.0	85.9	17.4	96.42	0.136
30-06-2012	33.9	26.5	95.1	77.8	4.6	99.10	0.201

*Mean of three replications

Table 2 : Simple correlation matrix between per cent disease index of Chrysanthemum leaf blotch disease with environmental variables

	Y (PDI)	Max. Tem. (x_1)	Min. Tem. (x_2)	Max. RH (x_3)	Min. RH (x_4)	Rainfall (x_5)
Y (PDI)	1.000					
Max. Tem. (x_1)	-0.159	1.000				
Min. Tem. (x_2)	0.664*	0.570	1.000			
Max. RH (x_3)	0.753**	-0.595*	0.257	1.000		
Min. RH (x_4)	0.832**	-0.635*	0.243	0.895**	1.000	
Rainfall (x_5)	-0.073	-0.704*	-0.635*	0.121	0.356	1.000

Table 3 : Simple correlation matrix between rate of spread of chrysanthemum leaf blotch disease with weather variables

	Y (PDI)	Max. Tem. (x_1)	Min. Tem. (x_2)	Max. RH (x_3)	Min. RH (x_4)	Rainfall (x_5)
Y (PDI)	1.000					
Max. Tem. (x_1)	- 0.121	1.000				
Min. Tem. (x_2)	-0.671*	0.653*	1.000			
Max. RH (x_3)	- 0.228	- 0.795*	- 0.168	1.000		
Min. RH (x_4)	- 0.496	- 0.746*	0.008	0.892**	1.000	
Rainfall (x_5)	- 0.199	- 0.801*	- 0.269	0.697*	0.826*	1.000

Table 4 : Multiple regression equations for prediction of Chrysanthemum leaf blotch disease intensity

Regression equations	COMD R^2	Adj. R^2	Multi R
$Y_{PDI1}{}^{*} = -702.398 + 15.486x_1 - 5.754x_2 - 0.661x_3 + 6.265x_4 - 1.296x_5$	0.934	0.824	0.966
$Y_{PDI2}{}^{**} = -774.876 + 16.279x_1 - 6.164x_2 + 6.184x_4 - 1.214x_5$	0.934	0.867	0.966
$Y_{PDI3}{}^{**} = -649.842 + 10.379x_1 + 5.019x_4{}^{**} - 0.782x_5$	0.932	0.891	0.965
$Y_{PDI4}{}^{**} = -750.790 + 12.900x_1{}^{**} + 5.114x_4{}^{**}$	0.921	0.894	0.959

different dates of observation were worked out and presented in Table 1. PDI increment exhibited gradual upward trend with the advancement of dates of observation while rate of spread of disease worked out between dates of observation showed initial declining trend followed by increasing trend at the latter stage. Weather parameters apparently did not exhibit any definite trend. Tak-

Table 5 : Multiple regression equations for prediction of rate of spread of Chrysanthemum leaf blotch disease

Regression equations	COMD R^2	Adj. R^2	Multi R
$Y_{ROS1}^{**} = 5.097 - 0.201x_1^{**} + 0.0165x_2^{**} + 0.004x_3 - 0.037x_4^{**} + 0.001x_5$	0.999	0.997	1.00
$Y_{ROS2}^{**} = 5.354 - 0.206x_1^{**} + 0.168x_2^{**} + 0.002x_3 - 0.036x_4^{**}$	0.997	0.993	0.998
$Y_{ROS3}^{**} = 5.657 - 0.211x_1^{**} + 0.172x_2^{**} - 0.0.037x_4^{**}$	0.996	0.992	0.998

ing PDI (Y_{PDI}) and rate of spread (Y_{ROS}) of disease and five weather variables *viz.* maximum temperature (x_1), minimum temperature (x_2), maximum relative humidity (x_3), minimum relative humidity (x_4) and rainfall (x_5) in consideration, two simple correlation matrices were worked out (Tables – 2 and 3).

It was evident from the Table 2 that maximum- (r = 0.753**) and minimum relative humidity (r = 0.832**) and minimum temperature (r = 0.664*) were positively and significantly correlated with PDI. Maximum temperature did not show any relation with PDI but exhibited significant positive relationship with minimum temperature whereas significant negative relationship with maximum and minimum relative humidity and rainfall.

Minimum temperature was the only environmental variable significantly and negatively correlated (r = 0.671*) with the rate of spread of disease (Table 3). Maximum temperature did not show any relation with rate of spread of disease also but exhibited significant positive relationship with minimum temperature whereas highly significant negative relationship with maximum and minimum relative humidity and rainfall. So, the increment of maximum temperature lowers the relative humidity.

In the present experiment multiple regression analyses were performed following backward methods to handle five number of independent weather variables and to identify critical and much contributory weather variable(s) separately towards the dependent variables *viz.* PDI (Y_{PDI}) and rate of spread (Y_{ROS}) of blotch disease. Results of the multiple regression analyses for prediction of the leaf blotch disease intensity alone with the calculation of coefficients of multiple determination (R^2) revealed that 92.1 % of total 93.4 % variations exist in the regression analysis of disease intensity can be accounted for by the linear function involving maximum temperature and minimum relative humidity (Table 4). The combined positive effect of these two weather parameters, identified as critical, contributed much towards the PDI increment. The representative and best fitted multiple regression equation for prediction of Chrysanthemum leaf blotch disease intensity appears to be $Y_{PDI4}^{**} = -750.790 + 12.900x_1^{**} + 5.114x_4^{**}$. Multiple regression analyses were also performed for the prediction of rate of spread of leaf blotch disease alone with the estimation of coefficients of multiple determination (R^2). Results of the experiment exhibited that out of total 99.9% variations explained by five weather variables, 99.6% variation was taken care of by three variables viz. maximum and minimum temperature and minimum relative humidity (Table 5). Minimum temperature has positive but maximum temperature and minimum relative humidity have negative impacts on rate of spread of disease. Considering the significant influence of these three weather parameters on the rate of spread of leaf blotch disease, they were identified as critical. The representative and best fit multiple regression equation for prediction of rate of spread of Chrysanthemum leaf blotch disease intensity seems to be $Y_{ROS3}^{**} = 5.657 - 0.211x_1^{**} + 0.172x_2^{**} - 0.0.037x_4^{**}$.

It was evident from the above studies of simple correlation coefficients between weather parameters and PDI that maximum- [87.2 - 95.1%] (r = 0.753**) and minimum relative humidity [58.0 – 85.9%] (r = 0.832**) and minimum temperature [22.9 – 28.8 °C] (r = 0.664*) were positively and significantly correlated with PDI *i.e.* the increment of maximum temperature, minimum and maximum relative humidity enhanced leaf blotch disease intensity. Present findings of the role of relative humidity and temperature on disease development were in the same line as obtained by Waddell (1959) wherein it was indicated that the disease was particularly severe during and after monsoon with mild temperatures (68-89°F *i.e.* 20 – 30°C) and high humidity or moisture. Ghosh *et al.* (2009) indicated highest and fastest progress of leaf blotch disease during warm and wet (rainy) months. Under field condition, large number of factors is known to be responsible for influencing disease intensity.

Of them, weather parameters are important. Out of five weather parameters considered for studying their influence on the increment of disease intensity, maximum temperature [32.5 – 38.4 ^{0}C] and minimum relative humidity [58.0 – 85.9%] were identified as critical parameters through multiple regression analysis and had their significant positive contributions towards the PDI increment *i.e.* increment of maximum temperature and minimum relative humidity from lower to higher range predicts higher disease intensity taking care of 92.1% variation out of total variation of 93.4%. Present findings about the role of maximum temperature [32.5 – 38.4 ^{0}C] on disease intensity increment contradict with the findings of Chandel and Chandel (2010) wherein they reported that leaf blotch disease severity was highest at 25^{0}C and lowest at 35^{0}C temperatures but confirm the role of relative humidity on increment of disease intensity. They observed that the disease usually appeared in field during June and reached to maximum in August with rise in relative humidity and rainfall. Through simple, partial and multiple correlations studies, they established that rainfall and relative humidity had positive effect while temperature had a negative effect on disease development. They also found that positive weather factors of disease development explained 66.03% out of 67.40% total variation through the co-efficient of multiple determinations whereas we found that maximum temperature and minimum relative humidity signified 92.1% variation out of total 93.4% variations.

Simple correlation coefficient studies between weather parameters and rate of spread of disease indicated that minimum temperature [22.9 – 28.8 ^{0}C] (r = 0.671*) was negatively and significantly correlated with rate of spread of the disease. When other weather parameters were considered together during multiple regression analyses and removed non-performing variables one by one, three weather variables viz. maximum and minimum temperature and minimum relative humidity were identified as critical for the prediction of rate of spread of leaf blotch disease. Increment of maximum temperature and minimum relative humidity significantly reduced rate of spread of disease while increment of minimum temperature significantly augmented the same. Out of total 99.9% variations explained by five weather variables, 99.6% variation was taken care of by the three variables viz. maximum and minimum temperature and minimum relative humidity. Little work has been done to see the effects of weather parameters on the rate of spread of Chrysanthemum leaf blotch disease. However, Chandel and Chandel (2010) reported that relative humidity more than 96% influenced the spread of Chrysanthemum leaf blotch disease to maximum by causing 57.2% disease severity.

In the present experiment we studied the increment of disease intensity/ PDI and rate of spread of disease under the same set of five different weather variables for fixed duration. Within this duration, increment of disease intensity/ PDI exhibited significant negative simple correlation (r = -0.765*) with the rate of spread of disease. The increment of maximum temperature and minimum relative humidity, identified as critical parameters for both PDI increment and rate of spread of disease through the multiple regression studies, exhibited positive effect on PDI increment while the augmentation of same parameters showed negative effect on the rate of spread of disease. However, from the regression of the rate of spread of disease it was additionally noted that the enhancement of minimum temperature caused significant positive contribution towards the increment of the rate of spread of disease.

CONCLUSION

It can be concluded from the above experimental results that out of five independent weather variables considered for prediction of dependent variables *viz.* disease intensity and rate of spread of disease, maximum temperature and minimum relative humidity were identified as critical weather parameters for both dependent variables following multiple regression analyses by backward method. They exhibited significant positive and negative effects on disease intensity and rate of spread of disease respectively. But minimum temperature increment caused significant positive contribution towards the increment of the rate of spread of disease as revealed by its multiple regression equation.

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