Journal of Agrometeorology
ISSN : 0972-1665 (print), 2583-2980 (online)
Vol. No. 24(3) : 318-320 (September 2022)
https://journal.agrimetassociation.org/index.php/jam

Short Communication

Prediction model for forewarning nursery wilt risk period in black pepper

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Black pepper (*Piper nigrum* L.), is a high-value historic spice crop that is mainly cultivated in Vietnam, Indonesia, India, Malaysia, Brazil, and Sri Lanka. It is valued for its characteristic aroma, pungent and biting taste and is mainly used for flavoring and seasoning. Black pepper is grown commercially in the southern part of India, but in some states in North-East India predominantly Assam is also engaged in the production. Black pepper cultivation in Assam covers 3428 ha area, producing 1833 tons of peppercorn (Kandiannan, 2018).

Black pepper production is challenged by about 17 diseases, one of them being foot rot or nursery wilt (Thomas and Naik, 2017). Nursery wilt is caused by *Phytophthora capsici*, an oomycete soil-borne phytopathogen that causes 30%-40% yield loss in Indonesia (Nam, 2012), more than 95% loss in Malaysia, and up to 30% yield decline in India (Anandaraj, 2002). For disease establishment, there should be proper optimization of all variable factors (host, pathogen, and environment) at correct and for sufficient time. All factors and elements should be in favor of pathogen for epiphytotic (Graham and Vance, 2003). A study on the role of weather parameters on the epidemiology of foot rot in Karnataka was carried out by Shamarao and Siddaramiah (2002). However, information regarding the relationship between nursery wilt incidence and weather variables is still lacking. Therefore, the present study was piloted up intending to investigate the role of different weather parameters on the natural occurrence of nursery wilt in Assam and develop a forecasting model to prewarn the farmers about the disease risk as well as to develop a comprehensive approach for sustainable and eco-friendly management of nursery wilt. The mathematical model was constructed using Binary Logistic regression which was further validated. The accuracy of the model was scrutinized and fitness was examined to display the real facet of the black pepper and nursery wilt pathosystem.

The experiment was carried out at Assam Agricultural University, Jorhat Assam (26.7248° N, and 94.1956° E, 116m). The experiment was designed in a randomized complete block design with four replications, each including 100 pepper plants. The size of each plot was 1m×1.5 m with spacing of 50 cm x 50 cm. Black pepper plants belonging to the variety Panniyur I was used as experimental material. Proper recommended horticultural practices were followed, no chemical and biocontrol agents were sprayed, and natural epidemic conditions allowed for the proper establishment of the disease.

Disease scoring

The disease incidence (DI) on plants was recorded weekly and calculated by following the formula laid by Wheeler, (1969),

$$\text{Disease incidence (\%)} = \frac{\text{Total number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Weekly data of different weather parameters *viz.* maximum temperature (T_{max}), minimum temperature (T_{min}), rainfall (RF), relative humidity (RH), and the number of rainy days (RD) for the years 2019-2020 and 2020-2021 was obtained from the Department of Agrometeorology, Assam Agricultural University, Jorhat-13, Assam.

Obtained data were further analyzed using binary logistic regression to develop a prediction model where disease risk and non-risk period (1/0) was considered as the dependent variable, and weather parameters as independent variables.

Binary logistic regression

This special type of regression is designed for modelling a categorical dependent variable.

$$Y_k = b_o + b_1x_1 + b_2x_2 + b_3x_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + b_kx_k$$

Article info - DOI: https://doi.org/10.54386/jam.v24i3.1667
Received: 15May 2022; Accepted: 27 July 2022; Published online: 31 August 2022
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Where, Y_k is the predicted value of Y, b_1 is the change in the mean of Y per unit change in x_1, b_0 is Y intercept (same as simple regression)

Using Logit model;

Logit (p) = In[p/1-p]; p = 1/ 1+ e-logit (p)

Where, "ln" is the natural logarithm, e=2.71828, "p" is the probability of the event i.e. disease risk which equals 1, p (Y=1), and non-risk equals 0, 1 – p(Y=1)

Odds = p/(1-p) (i.e. ratio of disease risk and non-risk)

$$Odds = p/1\text{-}p = e^{bi}Xe^{b_1x_1}\,Xe^{b_2x_2}\,Xe^{b_3x_3}\,\ldots\ldots\ldots\ldots\ldots\ldots\ldots Xe^{b_kx_k}$$

This means when Xi variable increases by 1 unit, with all other factors remaining same, then the odds will increase by factor e^{bi}.

Data analysis

Response of *Phytophthora* nursery wilt to different weather parameters was analyzed through Statistical Package for Social Sciences (SPSS) developed by the University of Stanford, California and the level of significance and association effects were evaluated. The recorded percent disease incidence value was subjected to arcsine transformation (Gomez and Gomez, 1984) before carrying out an analysis of variance (ANOVA).

The weekly data on weather parameters were acquired and corresponding to it DI was scored (Fig. 1). The conditions where DI was above 13% were considered a disease risk period and DI below 13% was considered a disease non-risk period. To unveil the impact of weather factors recorded data over two experimental years were put in binary logistic regression. Binary logistic regression is used for modelling dichotomous dependent variables (probability of the event here assumed 1 for disease risk and 0 for the non-risk period). Five independent variables were used for the construction of the model. The ANOVA in connection with the predicted DI of nursery wilt in black pepper unveiled that RF, RH, and RD were statistically significant contributors to the prediction model which was confirmed by p value= 0.03366, 0.041, 0.042 respectively (<0.05) (Table 1). Whereas, T_{max} and T_{min} were found to be non-significant with p value=0.21 and 0.11, respectively (0.05). The odd ratios of T_{max} (2.2) and T_{min} (2.1) show every 1 unit increase in temperature affects disease risk as minimum as 6% and a unit decrease in temperature increases disease risk by 9%, as *Phytophthora capsici* prefers cool temperature. However, the coefficient values for RF (1.25), RD (1.13), and RH (1.35) and odds ratios of 3.23, 3.11, 3.41 respectively signifies that these factors produce enhanced disease risk of 3.23, 3.11, 3.41 times as compared to T_{max} and T_{min} when other factors in the model remain constant. VIF (various implies factor) value shows the interaction among the predictors and the value 1.14 denotes that RF, RD, and RH are moderately associated (Table 1). The goodness of fit was also confirmed (Table 2) showed a high p-value ranging from 0.582 to 0.744 showing that our prediction model is reliable to accept.

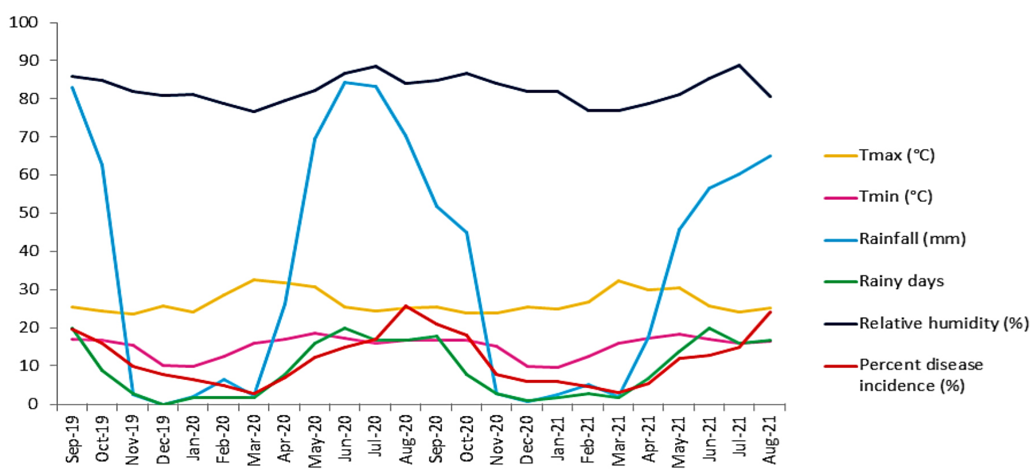

Fig. 1 : Mean average data on weather parameters and nursery wilt incidence during 2019-2021

Table 1: Binary logistic regression for predicting occurrence of nursery wilt

Weather predictors	Coefficient	SE	t-value	P-Value	VIF	Odd ratio	Class Interval	
							Lower	Upper
Constant	2.624							
T_{min}	-0.097	0.046	-2.097	0.118	0.41	1.06	23.9	32.64
T_{max}	0.056	0.046	1.224	0.213	0.23	1.09	10.01	18.76
RF	1.25	0.008	0.456	0.0336	1.14	3.23	0	84.58
RD	1.13	0.031	0.371	0.042	1.14	3.11	0	20
RH	1.35	0.046	-0.153	0.041	1.14	3.41	76.9	89

Table 2: Goodness of fit

Method	Chi square	P-value
Pearson	20.16	0.618
Deviance	16.19	0.744
Hosmer-Lemeshow	6.48	0.582

Development of model for Jorhat, Assam

The model developed for nursery wilt in Assam, India condition using Binary logistic regression is as follows:

P(1) = exp(Y')/(1 + exp(Y')

Y'= -2.62 + 1.25 RF + 1.13 RD + 1.35 RH [R^2= 0.66, R^2adj= 0.62]

Weather parameters that were found to be statistically significant were considered for model preparation. To find out the Y'a value one has to put values of RF, RD, and RH only. If the Y'a value is exceeding the cut-off value then the chances of disease occurrence are high. However, the Adjusted R^2 value shows that with the addition of insignificant variables, an increase in the R^2 value may be seen but R^2adj value will decrease. The high adjusted R^2 value shows the high efficiency of the developed model to predict nursery wilt.

Model validation

The final model was validated by comparing the predicted disease incidence with the actual observed disease incidence during 2021-22. The prediction model was validated satisfactorily (R^2=0.66). Disease prediction model clearly suggested RF, RD and RH as the important weather parameters that influenced nursery wilt occurrence in Assam environment. Apart from satisfactory validation, the model also revealed the significance of these three weather parameters in influencing host pathogen interaction. Empirical pathogen-weather models make significant contribution in in understanding host x pathogen dynamics but these models are location-specific (Teng *et al*. 1998). Various forecasting models have been developed *viz* model for early blight in potato (Saha and Das 2013), anthracnose in betel vine (Sahoo *et al*. 2012) downy mildew in pearl millet (Kumar *et al*. 2010).

Phytophthora wilt of black pepper causes huge loss ranging from 12%-80% in nurseries of Assam. Once the plant is infected with this pathogen it is really difficult to get back the healthy plant with the use of any fungicides. So, this prediction model will help farmers with prophylactic spraying of fungicides as well as researchers in the study of black pepper and nursery wilt pathosystem in the future. Apart from predicting disease this model also tells the most vulnerable crop stage for disease establishment.

Conflict of Interest Statement: The author (s) declares (s) that there is no conflict of interest.

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