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Research Paper

Forecasting models for forewarning Anthracnose and Web blight of mung bean (Vigna radiata) under Tarai Zone of Uttarakhand

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ABSTRACT

Mung bean (*Vigna radiata* L.) is attacked by numerous diseases of which anthracnose and web blight are predominant in Tarai Zone of Uttarakhand. Anthracnose and web blight of mung bean are caused by *Colletotrichum lindemuthianum* and *Rhizoctonia solani*, respectively. Their occurrence and development are highly influenced by weather conditions during the cropping season. Based on epidemiological data recorded at Pantnagar for two consecutive years (2019 and 2020), disease predictive models were developed using stepwise multiple regression. The result from the recorded data revealed that rainfall, $T_{(min)}$, rainy days, and morning relative humidity were statistically significant. Whereas, the $T_{(max)}$, evening relative humidity, and bright sunshine hours were statistically non-significant. Significant weather parameters were employed to develop suitable web blight and anthracnose prediction models for commonly grown varieties of mung bean. The prediction models were further validated using the web blight and anthracnose incidence data collected in mung bean varieties in 2021. The root mean square error values varied between 0.0002 – 0.0011, which shows that the models are accurate and acceptable.

Keywords: Web blight, anthracnose, mung bean, weather parameters disease incidence, correlation

Mung bean (*Vigna radiata* L.) is one of the most significant pulse crops, belongs to the family Leguminosae commonly known as green gram and it is also known as "Golden gram" because of its nutritional richness. It is a fast-growing short-term pulse crop grown in summer and autumn with the least input requirement and performs well under heat and drought conditions. Mung bean is grown primarily in tropical and subtropical areas like India, China, Bangladesh, Myanmar, Indonesia, Thailand, and some parts of central and eastern Africa, the United States of America, and Australia.

With increasing population growth in India, the major constraints in the cultivation and production of mung bean are low soil fertility, abiotic stress, unavailability of resistant cultivars, insect pests, and diseases. The diseases are mainly incited by different plant pathogenic microorganisms viz; fungus, bacteria, virus, phytoplasma, nematodes, etc which causes remarkable yield loss across the globe. Among the biotic stress, the fungus caused major diseases in mung bean such as Mung bean Web blight (*Rhizoctonia solani*), Anthracnose (*Colletotrichum lindemuthianum*), Cercospora leaf spot (*Cercospora canesens*), Powdery mildew (*Erysiphe polygoni*), Rust (*Uromyces phaseoli*) and Dry rot (*Macrophomina phaseoliana*), viral diseases are Yellow Mosaic (MYMV), and some major bacterial diseases like Bacterial leaf spot (*Xanthomonas phaseoli*) causing yield losses up to 40-60%. All the pathogenic fungi can infect the plant at various stages of development viz; germination, seedling emergence, and vegetative and reproductive stage. Among the major diseases, web blight and anthracnose are the economically important disease-causing major yield losses across the globe. Web blight caused by *Rhizoctonia solani* is one of the major foliar disease-causing yield losses ranging from 20-60 percent across the globe. In India, the disease cause reduction of 33 to 40 per cent in grain yield and 28.6 per cent in 1000 grain weight at a different level of disease severity (Gupta *et al.,* 2010). *Rhizoctonia solani* causes aerial symptoms on the lower portion of the plant that frequently occurs during the late vegetative growth stage. It is also responsible for pre- and post-emergence rot of mung beans and causing maximum mortality of seedlings (Kaiser, 1970).

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Initially, the symptoms on the leaf start as water-soaked, greyish green lesions which turn tan to brownish at maturity. The pathogen may infect leaves, pods, and stems near the basal area of the plant.

Whereas, anthracnose is caused by *Colletotrichum lindemuthianum* and is rewarded as a havoc disease of mung bean. The disease appears at any stage of growth specifically on all aerial parts of plants. Initial symptoms appeared on the lower surface of the leaf and spread to the leaf petiole, stem, and also on pods. There is an appearance of circular, black, sunken spots with a dark center and bright red-orange margins on leaves and pods. Anthracnose is also one of the causes of yield loss induced by pathogens in the crop if left uncontrolled. Anthracnose causes a wide range of loss in yield estimated at 24 to 67 per cent (Deeksha and Tripathi, 2002; Shukla *et al.,* 2014) from the several mung bean growing areas across the country. Even disease may reach up to 18.2 to 86.57% severity (Laxman, 2006).

The incidence and severity of both diseases are greatly influenced by various epidemiological parameters viz., temperature, relative humidity, bright sunshine hours, and rainfall which play a crucial role in the initiation and development of disease over time. (Thakur, 1988). Different disease prediction models such as the model for Alternaria leaf spot in apple (Huang *et al*., 2022), 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) and anthracnose in soybean (Bhatt *et al.,* 2022), anthracnose in black pepper (Verma and Chakrawarti, 2022) are developed to elucidate the influence of weather factors on host-pathogen interaction and which could prove helpful in monitoring and analyzing the occurrence of plant disease epidemics in nature for quantification and prediction of crop losses for setting strategies for the management of the disease (Nutter, 2007). Thus, the present study was carried out to analyze the correlation of weather factors with the incidence of web blight and anthracnose of the mung bean to find out the combination of weather conditions responsible for the occurrence of the disease under epiphytotic conditions. The mathematical models were constructed using stepwise regression whose accuracy was determined and further validated.

MATERIALS AND METHODS

A two-year field study was carried out in 2019 and 2020 at the Crop Research Centre (CRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S Nagar Uttarakhand (29.0229° N, 79.4879° E, 243.8 m), to investigate the role of weather factors on anthracnose and web blight incidence on ten mung bean varieties *viz.* IPM-2-3, IPM-2-14-9, MH-2-15, Pant Mung 4, Pant Mung 6, Pusa-0672, Pusa-1371, SML-1839, SML-2015 and VBN-4. The sowing of all ten varieties was done on 25th July 2019 and 20th July, 2020, in a randomised block design (RBD) with three replications. Each experimental plot measured 3 x 3 m^2 with of spacing 30 cm x 10 cm. The soil of the experimental field was silty loam with a pH of 6.5. All the recommended agronomical practices for the crop were followed, no fungicides were sprayed, and complete natural epiphytotic conditions allowed for the proper establishment of the disease in the field.

Collection of data on weather factors

The daily data on different weather factors *viz*. maximum (T_{max}) and minimum temperature (T_{min}), bright sunshine hours (BSH), rainfall (RF), morning relative humidity (RH I), evening relative humidity (RH II %), and rainy days (RD) were obtained from the Department of Agrometeorology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand.

Disease scoring (%)

From each replication, 30 plants were marked randomly. The number of mung bean plants showing web blight and anthracnose symptoms was counted and percent disease incidence (PDI%) was calculated using the formula (Wheeler, 1969):

$$\text{Disease incidence}(\%) = \frac{\text{No. of infected plants}}{\text{No. of plants observed}} \times 100$$

The PDI for each variety was recorded at the weekly interval, during 2019-2020. Disease reaction of each variety was determined by using rating scale developed by Bhattacharjee *et al*., (2019) for anthracnose and Anupriya and Chawla (2022) for web blight.

The mean area under the disease progress curve (AUDPC) for each replicate was calculated as follows (Pandey *et al.,* 1989).

$$AUDPC = \sum_{i=1}^{k} \frac{1}{2}(S_i + S_{i-1})d$$

Where k = No. of successive evaluation of disease; i = period; S_i = last disease severity; S_{i-1} =first disease severity; d = time interval

Infection rate (r) is the increase or decrease in disease per unit of time. It was calculated using the formula given by (Vanderplank, 1963).

$$r = \frac{2.3}{t_2 - t_1} \, log10 \, \frac{x_2(1 - x_1)}{x_1(1 - x_2)}$$

Where, r = infection rate; x_1 and x_2 are disease at time and , respectively

Analysis of data

All the parameters were transformed into a weekly mean, except for the rainy days. The weekly PDI data were expressed as cumulative PDI (%). Simple Pearson correlation analysis was carried out to determine the influence of weather on two pathosystems i.e., (mung bean × web blight) and (mung bean × anthracnose) and the significant weather factors for both web blight and anthracnose disease incidence. The significant weather parameters were considered for the development of the prediction model.

Moong bean varieties were classified in to two groups i.e. susceptible and non-susceptible based on disease reaction. Stepwise multiple regression analysis was employed for the development of models for susceptible and non-susceptible varieties to predict web blight and anthracnose incidence in mung bean varieties. The weekly data (obtained during 2019-20) of weather parameters (web blight and anthracnose incidence as dependent variables and weather factors as independent variables) were used. All the statistical analysis was accomplished through SPSS (Statistical Package for Social Sciences) developed by the University of Stanford, California.

Model validation

Models were validated in 2021during which all the ten varieties were sown on 20th July, 2021 at CRC, G. B. Pant University of Agriculture and Technology, Pantnagar, U.S Nagar Uttarakhand. Experimental design was RBD with three replications. Each experimental plot measured 3 x 3 m^2 with of spacing 30 cm x 10 cm. All the recommended agronomical practices for the crop similar to the crop sown in 2019 and 2020 were followed.

For the models' validation, the incidence of web blight and anthracnose for different varieties of mung bean was predicted by fitting the predictor variables of the 2021 dataset into respective models and comparing the predicted disease incidence with the actual disease incidence during the same year. To determine the performance of models, Root Mean Square Error (RMSE) was determined by the following formula:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (predicted - actual)^2}{N}}$$

Where, N is the number of samples

RESULTS AND DISCUSSION

Influence of weather factors on disease occurrence

The PDI, disease reaction, infection rate (r), and AUDPC for anthracnose and web blight of mung bean are presented in Table 1 and Table 2, respectively.

The web blight and anthracnose incidence were at their peak in August (2019-20), during which the weather parameters including RF, RD, and RH I were also high. Incidence of both diseases considerably reduced from September. Among the various weather parameters studied, T_{min} (0.51^{*} - 0.58^{*}), RF (0.81^{**} - 0.89^{**}), RD (0.75^{**} - 0.87^{**}), and RH I (77^{**} - 89^{**}) were found to be significantly and positively correlated with anthracnose. While RF (0.58^{*} - 0.69^{**}), RD (0.62^{**} - 0.68^{**}), and RH I (0.72^{**} - 0.78^{**}) were significant contributors to the web blight incidence (* and ** Represent significant at 5 and 1%, respectively).

Multiple regression model

Weather factors recorded to be statistically significant were employed for model development using stepwise multiple regression analysis. Most of the varieties were found to be susceptible for anthracnose and web blight. Therefore, common disease prediction model were constructed for both diseases. Data on disease incidence were pooled up and models for susceptible varieties were developed based on the two-year data (2019 and 2020). Mathematical model for Anthracnose prediction is

$Y = -32.4 - 0.43\ (T_{min}) + 0.40\ (RF) + 0.36\ (RH\ I) - 0.50\ (RD)$, T_{min}, RF, RD and RH I showed 86.2, and 83.2, percent variability in susceptible varieties ($R^2 = 0.76$ and $R^2_{adj} = 0.76$).

For web blight of mung bean prediction model is

$Y = -15.56 + 0.24\ (RF) + 0.68\ (RH\ I) - 0.82\ (RD)$, RF, RD and RH I showed 86.3 percent variability in susceptible varieties ($R^2 = 0.74$ and $R^2_{adj} = 0.74$), respectively.

To predict the disease incidence (Y value) one has to put the weekly average of weather parameters. High R^2_{adj} values show that the developed models are pretty good at predicting the disease.

Present epidemiological studies showed that disease incidence is highly influenced by weather factors. The findings are per the observations of other researchers in developing prediction models for disease assessment. Amrate *et al*., (2021) developed a disease forecasting model for the prediction of *Rhizoctonia* aerial blight of soybean with three significant weather variables (mean relative humidity, rainfall, and minimum temperature). Kulkarni and Raja (2019) studies indicate a negative correlation with temperature and a positive correlation with relative humidity and rainfall on per cent disease index and spore load of mung bean anthracnose.

Table 1: Per cent disease incidence (PDI), disease reaction, infection rate (r), and area under disease progress curve (AUDPC) for anthracnose of mung bean (2019-20)

Variety	PDI (%)		Disease reaction	Infection rate (r)		AUDPC	
	2019	**2020**		**2019**	**2020**	**2019**	**2020**
IPM-2-3	44.6±0.75	56.1±0.19	HS	0.005	0.006	534.37	635.03
IPM-2-14-9	31.7±1.37	51.4±0.21	S	0.004	0.005	468.44	532.26
MH-2-15	12.4±0.98	42.5±0.54	MS	0.002	0.005	239.47	418.59
Pant Mung 4	12.8±0.39	35.1±0.81	MS	0.002	0.004	285.68	348.13
Pant Mung 6	10.3±1.26	36.8±1.04	MS	0.001	0.004	198.17	382.86
Pusa 0672	46.9±1.05	59.6±1.48	HS	0.005	0.006	537.49	629.46
Pusa 1371	55.1±0.02	54.6±2.01	HS	0.006	0.006	684.24	674.67
SML 1839	58.3±0.61	58.7±0.18	HS	0.007	0.006	734.35	728.35
SML 2015	60.7±1.74	60.3±0.45	HS	0.015	0.007	784.12	780.09
VBN-4	9.4±٠,٢٩	29.6±٠,٤٨	MR	0.001	0.004	135.66	369.56

Here, ± Standard error; Moderately Resistant (MR), Moderately Susceptible (MS), Susceptible (S), Highly Susceptible (HS)

Table 2: Per cent disease incidence (PDI), disease reaction, infection rate (r), and area under disease progress curve (AUDPC) for web blight of mung bean (2019-20)

Variety	PDI (%)		Disease reaction	Infection rate (r)		AUDPC	
	2019	**2020**		**2019**	**2020**	**2019**	**2020**
IPM-2-3	56.1±0.32	62.0±0.21	HS	0.006	0.006	595.95	728.15
IPM-2-14-9	57.6±1.01	46.2±0.17	HS	0.016	0.006	456.47	389.58
MH-2-15	48.2±0.51	52.8±0.92	HS	0.005	0.006	514.34	513.46
Pant Mung 4	45.2±0.62	36.8±0.71	S	0.004	0.005	436.26	499.15
Pant Mung 6	46.8±0.83	49.2±0.62	S	0.004	0.005	383.35	517.25
Pusa 0672	46.3±0.65	52.1±1.18	S	0.004	0.006	575.74	523.57
Pusa 1371	52.7±1.63	44.2±0.45	S	0.005	0.005	535.24	484.37
SML 1839	16.3±0.15	32.8±0.12	MS	0.002	0.004	102.97	398.26
SML 2015	29.4±0.28	34.4±0.71	S	0.003	0.007	287.12	800.57
VBN-4	22.1±0.15	59.7±0.34	S	0.003	0.006	355.24	657.36

Here, ± Standard error; Moderately Susceptible (MS), Susceptible (S), Highly Susceptible (HS)

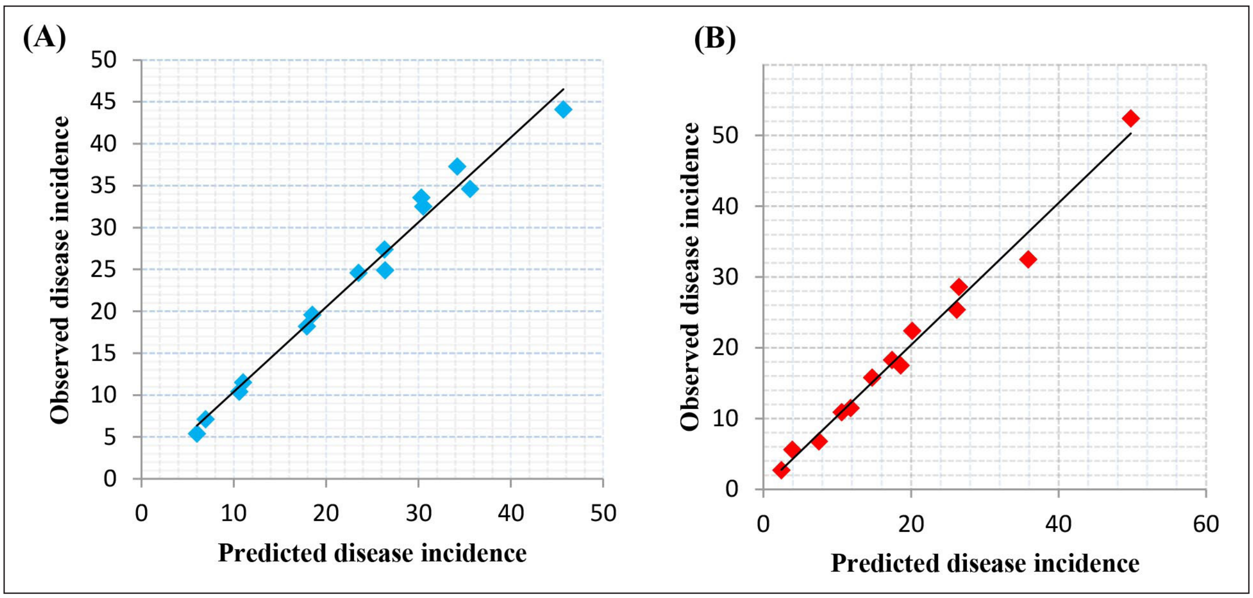

Fig. 1: Model validation: Predicted and observed (A) anthracnose and (B) web blight incidence graph (2021)

Sandhu *et al.,* (2021) investigated the relationship of stripe rust with weather parameters and weather-based prediction models were developed for the stripe rust by using disease severity and weather data (2007-08 to 2018-19) recorded at Ludhiana. The data of 2009-10 and 2019-20 was used for validation of model. Regression model based on maximum and minimum temperature, morning relative humidity and sunshine hours gave good results.

A similar experiment was conducted to estimate the influence of weather factors, soil temperature and soil moisture on the incidence of *Sclerotium rolfsii* Sacc., causing collar rot disease in betelvine (*Piper betle* L.), during 2016 to 2018. The result revealed that the soil moisture at 69 – 72% of field capacity, $T_{(min)}$ of 25 - 27ºC, $T_{(max)}$ of 33 - 36ºC, average soil temperature of 28 - 30ºC, $RH_{(min)}$ of 60 - 72 and $RH_{(max)}$ of 83 - 89 per cent inside the boroj are highly congenial for collar rot disease incidence (Garain *et al.,* 2021). Dar *et al.,* (2021) conducted and experiment in Northern Himalayas (India) for two consecutive cropping seasons (2017 and 2018) to develop a forecasting model against late blight of potato using stepwise regression analysis. $T_{(max)}$ and $T_{(min)}$ in the range of 15.0 – 28.0°C and 2.0 – 12.0°C were found favourable for potato blight disease. Similarly, relative humidity, rainfall and wind speed in the range of 85 – 95%, 15.5 - 20.75 mm and 1.0 - 5.5 Km/h, respectively also found conducive for potato late blight disease and its development. Bana *et al.,* (2020) showed that the disease incidence and disease severity of powdery mildew have significant negative relationship with morning relative humidity (r = -0.631; p<0.05 and r = -0.721; p<0.01) and average relative humidity (r = -0.766 and r = -0.787; p<0.01). The temperature (maximum and average) and evaporation showed positive relationship with disease incidence and severity of the disease. According to Kumar *et al.,* (2011), temperature ranging from 20 to 30ºC and RH ranging from

75 to 85% found to be optimum for the growth of *Fusarium* spp. The multiple regression analysis of pooled data (2013-2016) revealed that $T_{(max)}$ and $T_{(min)}$, number of rainy days and wind speed gradually influenced the development of Alternaria leaf spot (R^2=0.984) whereas, $T_{(min)}$ and evaporation influenced the development of grey mildew disease in cotton (R^2=0.976) (Bhattiprolu and Monga, 2018).

Models' validation

The prediction models for anthracnose and web blight were validated by comparing the predicted disease incidence with observed disease incidence in 2021. RMSE values were determined and they ranged from 0.0002 to 0.0011. Low RMSE values show that the developed prediction models are performing satisfactorily and can be employed in the future to detect the congenial weather conditions for anthracnose and web blight incidence in mung bean. Based on 2021 data, predicted and observed incidences of both diseases are plotted in Fig. 1**.**

CONCLUSION

The anthracnose and web blight in mung bean are highly influenced by weather parameters including $T_{(min)}$, rainfall, rainy days, and morning relative humidity in the Tarai Zone of Uttarakhand. Weather parameters found to be statistically significant were considered for the construction of models for commonly grown mung bean varieties. Models were validated satisfactorily with low RMSE values in 2021.

Looking at the devastating nature of diseases of mung bean, developed prediction models will help the growers of Tarai Zone of Uttarakhand to manage the disease prophylactically. Apart from predicting disease, prediction models will help future researchers in understanding the mung bean x anthracnose and web blight pathosystems.

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