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Epidemiology of greengram (*Vigna radiate*) anthracnose in northern Karnataka

Sunil Kulkarni and Raja

Abstract
The studies indicated that maximum spore counts of *Colletotrichum truncatum* were observed during last week of July and first week of August which coincided with the critical stages of infection to the pathogen. Further, 25 standard week was highly favorable for appearance and development of Anthracnose of greengram (*Vigna radiate* L.) spore load and per cent disease index of anthracnose indicated a negative correlation with temperature and positive correlation with relative humidity and rainfall. The multiple linear regression equations arrived for spore load and disease incidence were Y= 344.10-2.42 X_1 -8.32 X_2-.83 X_3 0.07 X_4 -0.07 X_5 and Y= 1349.88+16.37 X_1-75.27X_2 -2.72 X_3 +0.92 X_4 + 0.09 X_5.

Keywords: Greengram, disease, anthracnose, correlation, regression

Introduction
Anthracnose of greengram (*Vigna radiate* L. *wikzek*) caused by *Colletotrichum truncatum* (Schw.) Andrus and Moore is one of the major disease of greengram. The incidence of anthracnose widely fluctuate with various epidemiological parameters (Thakur, 1988) [9]. The environmental factors play a significant role in initiation and development of the disease. Epidemiological studies of the disease help in developing appropriate forecasting models to take up suitable precautionary measures for the management of disease. But in recent years the disease is appearing in severe form and has become one of the major constraints for greengram cultivation in parts of Northern Karnataka (Laxman, 2006) [6]. To forecast the disease severity and loss, the information on effect of environmental factors like temperature, relative humidity and rainfall in anthracnose disease management is very important in greengram (Thakur and Khare, 1991) [8]. Keeping this in view, studies on effect of weather factors on development of spore load of *Colletotrichum truncatum* and per cent disease index of anthracnose were carried out.

Materials and Methods
Aerobiology: Aerobiological studies were carried out to trap the conidia of *Colletotrichum truncatum* present in the air current. For this, aero scope exposure of stationary slide was done by mounting it on a wind wane and placed inside greengram field at ARS, Bidar. The crop was sown on first day of 24th standard week and harvested during 32nd standard week. The observations were made till the harvest of the crop.
A slide, which was smeared with a thin layer of vase line was used for trapping spores, by keeping smeared slide in the slot inside the box. The slide was removed every day at 08:30 hr. Average number of conidia per microscopic field was recorded under low power taking count of ten microscopic fields on a slide. Appearance of anthracnose disease on greengram crop in the aero spore installed field was recorded. Observations were made daily to record the first appearance of the disease in the field. In addition, the severity of disease was also recorded at weekly intervals starting from first appearance. Meanwhile, the weather data *viz.*, maximum and minimum temperature, morning and evening relative humidity and rainfall received during the period of aerobiological studies were recorded.
The information obtained from these observations were studied in relation to weather factors *viz.*, minimum and maximum temperature, rainfall and relative humidity (morning and evening) prevailed during the crop period by following standard statistical methods. The multiple regression equation was developed for estimation of spore load and PDI by taking weather parameters as input variables.

Effect of weather parameters in relation to spore load and severity of the disease
An attempt was made to study the effect of weather factors in relation to spore load and disease severity by subjecting the data to regression analysis.

The weather parameters were correlated to weekly spore load and weekly per cent disease index by calculating the Karl Pearson's correlation coefficient (r) as given below.

$$r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (xi - x)^2 \sum_{i=1}^{n} (yi - y)^2}}$$

Where

x and y are two variables
x : Mean of x
y : Mean of y
r : Karl Pearson's correlation coefficient

Further, the data were subjected to multiple linear regression analysis to find out the linearity of the independent variables for prediction.

Results

Aerobiology: As a part of epidemiology of the disease, aerobiological studies such as trapping of anthracnose conidia, first appearance of spores and disease and progression of spore load and development of disease were carried.

The investigation on sampling of air borne conidia of *C. truncatum* in greengram field was carried out throughout the cropping season under different environmental conditions, which was aimed primarily to understand the epidemiology of the disease. The pathogen was releasing the inoculum continuously in the form of conidia throughout the crop season. Hence, air sampling for presence of conidia was carried out by mounting spore trap in greengram experimental field. The data on intensity of anthracnose in relation to atmospheric spore load and weather parameters were presented in Table 1.

The data presented in Table 1 revealed that, the number of spores trapped daily varied as the disease severity progressed in the field. Air sampling carried indicated that, the first appearance of spores in the atmosphere was recorded after 13 days after sowing. The spore load gradually increased and reached peak of 22.14 during 31^{st} standard meteorological week (July 30 – August 05), while it was least during 25^{th} week (4.70). Similarly, PDI was also recorded lowest during 25^{th} standard week (9.26) and increased throughout the cropping period. It was peak during last stage *i.e.*, 32^{nd} standard week (SW) (68.50). During the cropping period maximum temperature ranged from 26.56^0C (31^{st} SW) to 34.51^0C (24^{th} SW), minimum temperature from 20.57^0C (31^{st} SW) to 23.60^0C (24^{th} SW), relative humidity (morning) from 77.43 per cent (24^{th} SW) to 96.00 per cent (31^{st} SW) and relative humidity (evening) from 37.14 per cent (24^{th} SW) to 79.14 per cent (31^{st} SW). However, rainfall was very erratic. It ranged from 1.5 mm (28^{th} SW) to 173.2 mm (31^{st} SW).

Correlation and multiple linear regression analysis between spore load of *C. truncatum* in relation to weather parameters

An attempt was made to establish the relationship between weather factors *viz.*, minimum and maximum temperature, morning and evening relative humidity and rainfall with spore load of *C. truncatum* through correlation and multiple linear regression analysis. The correlation coefficients are presented in Table 2.

The relationship between spore load of *C. truncatum* and weather factors indicated a negatively higher correlation between maximum and minimum temperature with a correlation coefficient of -0.821 and -0.891, respectively. While, relative humidity morning (0.762) and relative humidity evening (0.728) were significantly positively correlated with weekly spore load but rainfall was non-significantly positively correlated.

The multiple linear regression of spore load of *C. truncatum* in relation to weather parameters, indicated that regression coefficients for maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and rainfall were -2.42, -8.32, -0.83, 0.07 and -0.07, respectively (Table 3). The multiple linear regression equation was fitted to the data and the equation arrived for the weather parameters was $Y = 344.10 - 2.42 X_1 - 8.32 X_2 - 0.83 X_3 + 0.07 X_4 - 0.07 X_5$.

Where, X_1 = maximum temperature (^{0}C), X_2 = minimum temperature (^{0}C), X_3 = Relative humidity (%) morning, X_4 = relative humidity (%), evening and X_5 = rainfall (mm).

This explains that, when there is increase of one unit of maximum and minimum temperature, evening relative humidity and rainfall, the spore load was decreased by 2.42, 8.32, 0.07 and 0.07, while it was increased by 0.83 units with respect to morning relative humidity. The weather factors influenced the spore load of *C. truncatum* to the extent of 90.00 per cent.

Effect of weather parameters on the development and spread of anthracnose of greengram

The knowledge of weather conditions predisposing for development and spread of the disease is important to organize Agro Advisory Services (AAS) for the farmers to take up timely management practices.

Table.1. The anthracnose symptoms were first observed on 25^{th} SW, when the crop was at 19 DAS. The severity increased slowly and reached as high as 68.50 per cent during 32^{nd} SW. During the previous week, maximum temperature of 26.56^0C, minimum temperature of 20.57^0C, morning relative humidity of 96.00 per cent, evening relative humidity of 79.14 per cent and 173.2 mm rainfall were observed.

The data indicated that 25^{th} and 26^{th} standard weeks were highly favorable for the first appearance of the disease. The weather factors played an important role in the initiation and further spread of disease. It gives information to design supervisory control measures of disease in order to get expected yield.

Correlation and multiple linear regression analysis between severity of anthracnose in relation to weather parameters

The analysis was made to establish the relationship between weather factors *viz.*, maximum and minimum temperatures, morning and evening relative humidity and rainfall with per cent disease index of disease in highly susceptible variety 'Chinamung' through correlation and multiple linear regression analysis.

The relationship between PDI and weather factors (Table 4) indicated significant negative correlation between maximum and minimum temperature with a correlation coefficient of -0.837 and -0.909, respectively. While, relative humidity morning (0.741), relative humidity evening (0.721) and rainfall (0.575) were positively correlated with PDI.

The multiple linear regression of PDI in relation to weather parameters (Table 5) indicated that the regression coefficients for maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and rainfall were found to be 16.37, -75.27, -2.72, 0.92 and 0.09, respectively
The multiple linear regression equation was fitted to the data and the equation arrived for the weather parameters was $Y = 1349.88 + 16.37 X_1 – 75.27 X_2 – 2.72 X_3 + 0.92 X_4 + 0.09 X_5$, Where, X_1 = maximum temperature (^{0}C), X_2 = minimum temperature (^{0}C), X_3 = relative humidity (%) morning, X_4 = relative humidity (%) evening and X_5 = rainfall (mm).
This revealed that when there was increase in one unit of maximum and minimum temperature, the per cent disease index decreased by 16.37 and 75.27 units, respectively, while when there was increase in one unit of morning and evening relative humidity and rainfall, the per cent disease index increased by 2.72, 0.92 and 0.09 units, respectively. The weather factors influenced the disease incidence in Chinamung to the extent of 98.00 per cent.

Table 1: Effect of environmental factors in relation to spore load of *Colletotrichum truncatum* and disease progression during at ARS, Bidar

Std. week	Stage of crop (days)	Average weekly spore load	Weekly PDI	Temperature (^{0} c)		Relative humidity (%)		Total rainfall (mm)
				Maximum	Minimum	Morning	Evening	
24	6-12	0	0	34.51	23.60	77.43	37.14	4.4
25	13-19	4.70	9.26	32.49	22.37	89.57	55.86	20.2
26	20-26	14.32	13.58	31.26	21.91	92.86	58.00	18.4
27	27-33	20.43	21.65	30.23	21.66	90.71	62.43	8.7
28	34-40	18.50	29.32	31.46	21.94	86.86	51.71	1.5
29	41-47	15.21	38.02	32.34	21.86	88.14	49.00	8.8
30	48-54	17.10	50.11	28.74	21.14	94.86	71.00	83.4
31	55-61	22.14	62.21	26.56	20.57	96.00	79.14	173.2
32	62-68	20.75	68.50	29.03	20.69	95.86	63.71	17.9

Table 2: Correlation between weekly spore load of *Colletotrichum truncatum* in relation to weather parameters

S. No.	Weather parameters	Correlation coefficient (r)
1	Maximum temperature (ºc)	- 0.821**
2	Minimum temperature (ºc)	- 0.891**
3	Relative humidity (%) morning	0.762**
4	Relative humidity (%) evening	0.728*
5	Rainfall (mm)	0.393

** significant at 1% probability, * significant at 5% probability

Table 3: Multiple linear regression of spore load of *Colletotrichum truncatum* causing anthracnose of greengram in relation to weather parameters

Constant (a)	X_1	X_2	X_3	X_4	X_5	R^2
344.10	- 2.42	- 8.32	- 0.83	0.07	- 0.07	0.90

X_1 = Maximum temperature (ºc), X_2 = Minimum temperature (ºc), X_3 = Relative humidity (%) morning, X_4 = Relative humidity (%) evening, X_5 = Rainfall (mm), R^2 = Coefficient of determination

Table 4: Correlation between percent disease index (PDI) of anthracnose of greengram in relation to weather parameters

S. No.	Weather parameters	Correlation coefficient (r)
1	Maximum temperature (ºc)	- 0.837**
2	Minimum temperature (ºc)	- 0.909**
3	Relative humidity (%) morning	0.741**
4	Relative humidity (%) evening	0.721*
5	Rainfall (mm)	0.575*

** significant at 1% probability, * significant at 5% probability

Table 5: Multiple linear regression of percent disease index of anthracnose of greengram caused by *Colletotrichum truncatum* in relation to weather parameters

Constant (a)	X_1	X_2	X_3	X_4	X_5	R^2
1349.88	16.37	- 75.27	-2.72	0.92	0.09	0.98

X_1 = Maximum temperature (ºc), X_2 = Minimum temperature (ºc), X_3 = Relative humidity (%) morning, X_4 = Relative humidity (%) evening, X_5 = Rainfall (mm), R^2 = Coefficient of determination.

Discussion

Effect of weather factors on spore load of *C. truncatum*

The study on spore load of *C. truncatum* was carried out at ARS, Bidar and presented on weekly average in terms of standard week with meteorological data.
Air sampling carried indicated that, the first appearance of spore load in the atmosphere was recorded after 13 days of sowing and maximum spore counts were observed during last week of July and first week of August. Last week of July and first week of August as observed in 2006. The favourable weather conditions such as temperature, relative humidity and rainfall prevailed during these periods. Hence, there was increase in the spore load. These studies are in accordance with Thakur and Khare (1991) [8], they reported that maximum trapping of spores (*C. lindemuthianum* and C. *dematium*) was recorded when there was moderate temperature (26 – 29^{0}C), RH (91 – 96%) and rainfall (0 – 21.6 mm). Highest spore trap coincided with these conditions prevalent on July 30th. Similar results were reported by Ashok Kumar *et al.* (1999) [2].
Temperature was significantly and negatively correlated with weekly spore load during years. Higher temperatures are always detrimental for production and germination of spores as it leads to desiccation (Agrios, 1997) [1]. Relative humidity and rainfall have positive correlation with weekly spore load. Rain promotes the release of many fungal spores and is of particular significance in release of *Colletotrichum* spores as they are embedded in a gelatinous substance in the acervuli (Hirst and Steadman, 1963) [4]. Further, Sinclair and Backman (1989) [7] reported that anthracnose disease developed in soybean after prolonged period of high humidity and that the conidia of the fungus germinated and formed appressoria at temperatures below 35^{0}C when the plant surface was wet. Similarly, Zaumeyer and Thomas (1957) [10] reported that anthracnose fungus required cool temperature ranges for its growth, infection and development.
The variation in disease appearance and development in different localities may also be attributed to the prevalence of favourable weather conditions. The dissemination of conidia is almost exclusively by wind (Hirst, 1953) [5]. Thakur (1988) [10] reported that conidia of anthracnose were dispersed very efficiently by air. Air borne concentration follows the pattern of field disease incidence and can be used to assess the severity.
The multiple linear regression equation was fitted to the data and the equation arrived for all the weather parameters is, $Y = 344.10 – 2.42 X_1 – 8.32 X_2 – 0.83 X_3 + 0.07 X_4 – 0.07 X_5$. Hence, it is evident from the data that, all the weather factors

influenced the spore load of *C. truncatum* extent of 90 per cent it has influenced to the extent of 81.00 per cent.

Effect of weather parameters on development and spread of disease: Environmental factors decide the epidemic of anthracnose of greengram. The environmental factors like temperature, relative humidity and rainfall are important for disease development and these environmental factors are being used to forecast disease severity. Further, the knowledge of weather conditions for the development and spread of disease are important to organize Agro Advisory Services for the farmers to take up timely management practices.

The anthracnose symptoms were first observed on 25th standard week when the crop was at 19 DAS. The severity increased slowly and reached the incidence of 68.50 per cent during 32nd standard week. During the previous week, maximum temperature of 26.56^{0}C and minimum temperature of 20.57^{0}C with morning relative humidity of 96.00 per cent and evening relative humidity of 79.14 per cent was followed by 173.2 mm rainfall.

In general, frequent rains with moderate temperature (26 – 30^{0}C) and high relative humidity (85 – 96%) are essential for initiation and spread of the disease. The findings are in conformity with Ashok Kumar *et al.* (1999) [2], who reported that maximum anthracnose disease development was noticed after mid July to Mid August, when weather variables *viz.*, temperature (19 – 20^{0}C), relative humidity (74 – 77%), rainfall (0.2 – 166.9 mm) and frequency of rains (2 – 5 days) were congenial in kidney bean. Two consecutive days of rain accompanied by cloudiness and high humidity are necessary for infection of *C. truncatum* in bean (Chambers, 1969) [3]. Further, Thakur and Khare (1991) [8] reported excessive spore production when there was moderate temperature (26 – 29^{0}C), RH (91 – 96%) and rainfall (0 – 21.6 mm). Further, they noticed maximum increase in lesion size of greengram anthracnose when the relative humidity was 100 per cent followed by temperature 27^{0}C.

The analysis was made to establish the relationship between weather factors and per cent disease index of anthracnose in highly susceptible variety Chinamung through correlation and multiple linear regression analysis. The relationship between anthracnose PDI and weather factors indicated higher negative correlation between maximum and minimum temperature but positive correlation with morning and evening relative humidity and rainfall. The results are in agreement with Chambers (1969) [3], Thakur (1988) [9], Thakur and Khare (1991) [8] and Ashok Kumar *et al.* (1999) [2].

The multiple linear regression equation was fitted to the data and the equation arrived for all the weather parameters, $Y = 1349.88 + 16.37\ X_1 – 75.27\ X_2 – 2.72\ X_3 + 0.92\ X_4 + 0.09\ X_5$. Hence, the weather factors influence the disease incidence for 2006 to the extent of 98 per cent.

Conclusion

The aerobiological studies on effect of weather factors on the development of spore load of *C. truncatum* indicated that more conidial counts were observed during last week of July and first week of August, which coincided with the critical stages of infection. The correlation studies between spore load and weather parameters indicated a negative correlation with temperature, while relative humidity and rainfall have positive correlation with spore load. The studies on effect of weather factors on development of disease revealed that per cent disease index (PDI) was progressing at linear rate throughout the plant growth and it was negatively correlated with temperature, while positively correlated with relative humidity and rainfall. The study on date of sowing revealed that the greengram crop sown on 4th June showed least disease severity followed by crop sown on 11th June. Whereas, crop sown during 18th June and subsequent weeks, suffered a lot due to anthracnose. Temperature was negatively correlated with disease severity, while relative humidity and rainfall were positively correlated. The coincidence of the favourable period with stage of the crop led to considerable boost in disease incidence.

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