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Weather based Forecasting of Fungal Foliar Diseases of Bt. Cotton

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ABSTRACT: Cotton (*Gossypium* spp.) an important commercial crop called as king of fibres. It is known to be infected by many diseases such as Alternaria blight, grey mildew, rust and black arm of cotton. Disease development is mainly influenced by weather parameters such as maximum and minimum temperature, morning and evening relative humidity, rainfall and rainy days. Studies were conducted to assess the progress of fungal foliar diseases on two Bt genotypes of cotton (Bunny *Bt* and Dr. Brent *Bt*) in relation to weather parameters. The results revealed that significant negative correlation was observed for minimum temperature, morning and evening relative humidity, number of rainy days in both the genotypes with PDI of Alternaria blight alone and significant negative correlation was observed for minimum temperature, morning and evening relative humidity in both the genotypes with grey mildew PDI. The significant negative correlation was observed in cotton rust for minimum temperature, morning and evening relative humidity in both the genotypes. This study focuses on impact of weather parameters on fungal foliar diseases and tackles the problem as well.

Keywords: Alternaria blight, black arm, correlation, cotton, *Gossypium* spp., grey mildew.

INTRODUCTION

Cotton (*Gossypium* spp.) is popularly referred as "white gold" which belongs to the botanical family Malvaceae. Cotton is an important commercial crop called as king of fibres which aggregates a pre-eminent status and leading role among all the cash crops in the country and is foremost raw material for booming a textile industry (Prashant *et al*., 2019). India is the sole country where all four cotton species are grown because of the wide variety of agro-environmental and soil conditions that permits the cultivation of different species having varied staple length. Currently, production of cotton in the world is about 118.93 million bales of 480 lakh bales unit. Among the key producers in the world, India stands first in production with 270 lakh bales of 480 lakh bales unit followed by China, United States, Brazil and Pakistan. India has cultivable area of 122.5 lakh hectares with productivity of 480 kg ha^{-1}. Among the Indian states, Karnataka ranks sixth in area with 5.75 lakh hectares and eighth in production with 18.0 lakh bales of 170 kg with the productivity of 532 kg ha^{-1} (Anon., 2019).

The production potential of the crop has not been exploited to the full extent due to many abiotic and biotic factors. Cotton is affected by many foliar diseases. In India, foliar diseases of cotton like fungal, bacteria, viral and boll rot are calculable to cause yield losses of 20 to 30 per cent (Mayee and Mukewar 2007). Among the various foliar diseases, Alternaria blight (*Alternaria macrospora*), grey mildew (*Ramularia areola*), and rust (*Phakopsora gossypii*) are the major foliar diseases of cotton in Asia. Each need a temperature range of 20-30°C with prolonged high humidity (>80 %) and frequent rains for infection and malady development. However, it's been determined that cool weather as well as prolonged wet periods within the absence of rains has additionally been found causative for the occurrence of both diseases (Johnson *et al.*, 2013).

Balikai *et al.* (2019) reviewed the work on the development of models to predict insect pest populations based on weather factors. Jamadar *et al.* (2009) forecasted the powdery mildew disease incidence on ber (*Ziziphus mauritiana* Lam.) based on weather parameters. Similarly, many workers had studied the role of climatic factors on disease development in pomegranate plants (Hingorani and Singh 1959; Atulchandra *et al.,* 1994; Yenjerappa *et al,* 2006; Sharma *et al.,* 2012). Thus, weather factors play a predominant role indetermining the course and severity of epidemics. Hence, this investigation was aimed at studying the effect of weather factors on fungal foliar diseases of *Bt.* cotton.

MATERIAL AND METHODS

The disease development is mainly influenced by weather parameters, where in the interaction between the susceptible host and virulent pathogen can cause disease if only the favorable environment exists. Present studies were conducted in order to know the influence of different weather parameters *viz.*, temperature (maximum and minimum), relative humidity (morning and evening), rainfall both in the morning and evening hours, weekly rain fall and number of rainy days on the progression of fungal foliar diseases of cotton.

The present investigation was carried out at Agricultural Research Station, Hebballi Farm, University of Agricultural Sciences, Dharwad during 2018 in plot size of 9 ×6 m with the spacing of 90 × 60 cm for two Bt genotypes of cotton (Bunny *Bt* and Dr.Brent*Bt*) by adopting recommended agronomic practices. The crop was monitored for appearance of initial symptoms of Alternaria blight, grey mildew and rust on both the genotypes. The disease severity recorded by using 0-4 disease rating scale (Mayee and Datar 1986) and based on disease scores per cent disease intensity (PDI) was calculated by using below mentioned formula (Wheeler, 1969).

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves observed} \times \text{maximum disease score}} \times 100$$

Observations were recorded on development and progress of Alternaria blight, grey mildew and rust on weekly intervals from 31st to 46th standard meteorological weeks and it was correlated with the weather parameters. Effect of weather parameters such as minimum and maximum temperature, morning and evening relative humidity, rainfall and rainy day involved in the development of disease was assessed. Further, data was subjected to step wise linear regression analysis and multiple regression equations were developed for fungal foliar diseases (Alternaria blight, grey mildew and rust) on different varieties of cotton (Bunny *Bt* and Dr.Brent *Bt*).

RESULT AND DISCUSSION

The first symptom of Alternaria blight was observed on Bunny *Bt* and Dr. Brent *Bt* during 31st standard week, when crop was at 30 days after sowing with 4.38 and 4.06 PDI respectively. The severity of disease increased slowly and reached as high as 17.88 and 18.00 per cent respectively during 46th standard week where weekly mean maximum temperature of 31.21°C, mean minimum temperature of 15.56°, mean morning relative humidity of 61.00 per cent, mean evening relative humidity of 31.00 per cent and no rainfall was recorded in the week (Table 1).

Table 1: Influence of weather parameters on development of fungal foliar diseases in Bt. Cotton.

Standard meteorological week	Stage of crop (DAS)	PDI for Bunny Bt			PDI for Dr. Brent Bt			Temperature (°C)		Relative humidity (%)		Weekly rainfall (mm)	No. of rainy days
		Alternaria blight	Grey mildew	Rust	Alternaria blight	Grey mildew	Rust	Maximum	Minimum	Morning	Evening		
31	30	4.38	0	0	4.06	0	0	25.97	20.40	92.00	80.57	20.0	4
32	37	5.00	0	0	5.55	0	0	26.69	20.59	92.29	77.29	2.8	0
33	44	6.15	0	0	6.08	0	0	24.77	20.36	93.86	83.29	33.2	5
34	51	6.89	0	0	7.10	0	0	25.91	19.96	92.00	68.29	13.2	1
35	58	8.85	0	0	8.92	0	0	26.73	19.94	92.00	75.29	8.0	0
36	65	10.41	0	0	10.62	0	0	27.71	18.70	90.29	62.71	1.8	0
37	72	10.79	0	0	10.79	0	0	30.60	17.83	86.57	46.00	0.0	0
38	79	11.12	0	0	11.07	0	0	30.08	19.37	85.43	55.00	22.0	1
39	86	11.72	14.48	0	11.42	14.72	0	30.87	19.41	86.71	49.71	32.6	2
40	93	11.99	15.90	0	12.13	15.51	0	32.54	19.80	81.14	43.86	10.0	1
41	100	12.81	15.28	0	13.20	15.78	0	32.44	19.55	86.00	39.71	2.2	0
42	107	12.95	16.65	0	13.39	16.29	0	30.13	19.31	85.71	52.71	51.6	2
43	114	14.63	16.97	0	13.77	16.29	0	32.06	16.80	62.00	44.00	0.0	0
44	121	15.61	17.06	19.01	15.86	17.22	18.37	30.40	15.93	62.86	36.86	0.0	0
45	128	17.38	18.24	23.57	17.06	17.83	22.98	31.87	17.10	65.43	31.00	0.0	0
46	135	17.88	18.40	25.71	18.00	18.93	24.74	31.21	15.56	61.00	31.00	0.0	0

Note: DAS – Days after sowing
PDI – Per cent disease index

Grey mildew and rust symptom were initially observed on Bunny *Bt* during 39th and 44th standard week when crop was at 86 days after sowing with 14.48 PDI and 121 days after sowing with 19.01 PDI respectively. The severity of disease increased slowly and reached as high as 18.40 and 25.71 per cent during 46th standard week, where weekly mean maximum temperature of 31.21°C, mean minimum temperature of 15.56°C, mean morning relative humidity of 61.00 per cent, mean evening relative humidity of 31.00 per cent and no rainfall was recorded in the week (Table 1).

Grey mildew and rust symptom were initially observed on Dr.Brent *Bt* during 39th and 44th standard week when crop was at 86 days after sowing with 14.72 PDI and 121 days after sowing with 18.37 PDI respectively. The severity of disease increased slowly and reached as high as 18.93 and 24.74 per cent during 46th standard week, where weekly mean maximum temperature of 31.21°C, mean minimum temperature of 15.56°C, mean morning relative humidity of 61.00 per cent, mean evening relative humidity of 31.00 per cent and no rainfall was recorded in the week (Table 1).

Correlation and step wise regression analysis between severity of fungal foliar diseases in relation to weather parameter. The significant positive correlation of Alternaria blight in both the cotton genotypes with maximum temperature and significant negative correlation was observed with minimum temperature, morning relative humidity, evening relative humidity and number of rainy days as represented in Table 2.

The severity of grey mildew in both the genotypes showed significant negative correlation with minimum temperature, morning relative humidity, evening relative humidity and number of rainy days and significant positive correlation was observed with maximum temperature. The severity of rust showed significant negative correlation with minimum temperature, morning relative humidity and evening relative humidity in all the four genotypes and significant positive correlation was seen with maximum temperature in both cotton genotypes and results obtained are presented in the Table 2.

Then data was again subjected to step wise linear regression analysis and regression equations were developed for fungal foliar diseases on different varieties and hybrids of cotton which are represented below (Table 3).

The regression equation for Bunny *Bt* hybrid:

Alternaria blight, $Y = 32.83 - 0.009T_{max} - 0.47\ T_{min} - 0.05RH_1 - 0.15\ RH_2$ with $R^2 = 0.92$

Grey mildew, $Y = -2.57 + 0.15\ T_{max} + 4.37\ T_{min} - 0.72\ RH_1 - 0.29RH_2$ with $R^2 = 0.81$

Rust, $Y = 76.31 - 2.45\ T_{min} - 0.33\ RH_1 - 0.04\ RH_2$ with $R^2 = 0.63$

The regression equation for Dr. Brent *Bt* hybrid:

Alternaria blight:

$Y = 11.98 + 0.66\ T_{max} - 0.99\ T_{min} + 0.05\ RH_1 - 0.09\ RH_2 + 0.05NRD$ with $R^2 = 0.91$

Grey mildew: $Y = -13.4 + 0.42\ T_{max} + 4.38\ T_{min} - 0.71\ RH_1 - 0.26RH_2$ with $R^2 = 0.80$

Rust: $Y = 73.55 - 2.34T_{min} - 0.33\ RH_1 - 0.03\ RH_2$ with $R^2 = 0.63$

where

Y = Per cent Disease Index

T_{max} = Maximum temperature (°C)

T_{min} = Minimum temperature (°C)

RH_1= Relative humidity (Morning) (%)

RH_2= Relative humidity (Evening) (%)

NRD = Number of rainy days

Development of regression models based on predicted and observed values for fungal foliar diseases. Based on the regression equation, predicted values for disease can be determined by subjecting the observed values of disease to step wise regression analysis and severity of disease is plotted against standard meteorological week to develop validation models for fungal foliar diseases for two different varieties of cotton and results are presented below in Table 4 and 5.

Significant negative correlation was observed for grey mildew in susceptible Bt Cotton hybrid Jadoo BG II for maximum temperature and minimum temperature with per cent disease intensity. Multiple linear regression of PDI indicated that for every one per cent increase in evening relative humidity there was corresponding increase of 0.64 in per cent disease index of grey mildew spot and suggests preventive and / or protective measures are to be taken up with recommended fungicides like 0.3% wettable sulphur or 0.1% carbendazim (Bhattiprolu *et al*., 2017).

For cotton rust, significant negative correlation was observed with minimum temperature, morning and evening relative humidity in both the genotypes. The results obtained are in accordance with Bhattiprolu and Monga (2018). Where he observed the significant negative correlation with minimum temperature, evening relative humidity and number of rainy days on the progress of Alternaria blight. While in case of grey mildew minimum temperature, evening relative humidity, rainfall and number of rainy days had significant negative correlation.

Venkatesh *et al.* (2013) revealed that, minimum temperature during initial and progress stages of disease, and afternoon relative humidity during peak stage of disease was identified as critical to forecast the Alternaria blight disease in cotton genotypes.

Venkatesh *et al.* (2015) reported that grey mildew disease was initiated in August, increased in September and reached peak level in the month of October at Dharwad. Daunde *et al*. (2021) documented that rainfall (-0.531) had significantly negative correlation with the grey mildew disease development whereas Morning RH (-0.747) and Evening RH (-0.761) had highly significant negative correlation. Further, maximum temperature (0.342) and minimum temperature (0.052) showed positive non-significant correlation with grey mildew disease.

significant negative correlation was observed for maximum temperature and minimum temperature with per cent disease intensity, while morning relative humidity and sunshine hours were positive and significantly correlated. Multiple linear regression of PDI indicated that for every one per cent increase in morning relative humidity there was corresponding

increase of 0.80 in per cent disease index of Alternaria leaf spot and suggests preventive and / or protective measures are to be taken up with recommended fungicides like mancozeb and propiconazole (Venkatesh *et al*., 2016).

Table 2: Correlation values for fungal foliar diseases in relation to weather parameters.

Sr. No.	Weather Parameters	Correlation coefficient (r)					
		Bunny *Bt*			Dr. Brent *Bt*		
		AB	GM	Rust	AB	GM	Rust
1.	Max. Temp	0.829**	0.805**	0.344	0.822**	0.811**	0.344
2.	Min. Temp	-0.853**	-0.598**	-0.781**	-0.840**	-0.574**	-0.780**
3.	RH_1(%)	-0.867**	-0.769**	-0.781**	-0.736**	-0.749**	-0.781**
4.	RH_2(%)	-0.939**	-0.813**	-0.618**	-0.819**	-0.805**	-0.618**
5.	Total Rainfall	-0.306	-0.050	-0.390	-0.278	-0.040	-0.390
6.	No. of Rainy Days	-0.547*	-0.270	-0.317	-0.503*	-0.266	-0.317

Note: AB: Alternaria blight, **GM:** Grey mildew
** Correlation is significant at 1 per cent
* Correlation is significant at 5 per cent

Table 3: Step wise regression equations for fungal foliar diseases of different cotton varieties/ hybrids.

Varieties/ hybrids	Susceptible to	Step wise linear regression equation	r^2 value
Bunny *Bt*	Alternaria blight	$Y = 32.83 - 0.009T_{max} - 0.47\ T_{min} - 0.05RH_1 - 0.15\ RH_2$	0.92
	Grey mildew	$Y = -2.57 + 0.15\ T_{max} + 4.37\ T_{min} - 0.72\ RH_1 - 0.29RH_2$	0.81
	Rust	$Y = 76.31 - 2.45\ T_{min} - 0.33\ RH_1 - 0.04\ RH_2$	0.63
Dr.Brent *Bt*	Alternariablight	$Y = 11.98 + 0.66\ T_{max} - 0.99\ T_{min} + 0.05\ RH_1 - 0.09\ RH + 0.05NRD$	0.91
	Grey mildew	$Y = -13.4 + 0.42\ T_{max} + 4.38\ T_{min} - 0.71\ RH_1 - 0.26RH_2$	0.80
	Rust	$Y = 73.55 - 2.34T_{min} - 0.33\ RH_1 - 0.03RH_2$	0.63

Where,
Y= Per cent disease index RH_1 = Morning relative humidity
T_{max}= Maximum temperature RH_2 = Evening relative humidity
T_{min}= Minimum temperature NRD = Number of rainy days

Table 4: Development of prediction models for fungal foliar diseases of Bunny *Bt* cotton hybrid.

Hybrid: Bunny *Bt*												
Standard meteorological week	Per cent disease index											
	Alternaria blight				Grey mildew				Rust			
	Observed	Predicted	Deviation	Standard Residual	Observed	Predicted	Deviation	Standard Residual	Observed	Predicted	Deviation	Standard Residual
31	4.38	5.87	-1.49	-1.29	0.00	1.87	-1.87	-0.50	0.00	-2.70	2.70	0.48
32	5.00	6.27	-1.27	-1.10	0.00	0.17	-0.17	-0.05	0.00	-2.00	2.00	0.36
33	6.15	5.36	0.79	0.69	0.00	-2.33	2.33	0.62	0.00	-2.43	2.43	0.44
34	6.89	7.95	-1.06	-0.92	0.00	1.85	-1.85	-0.49	0.00	-1.42	1.42	0.25
35	8.85	6.90	1.95	1.69	0.00	-0.17	0.17	0.05	0.00	-1.08	1.08	0.19
36	10.41	9.52	0.89	0.77	0.00	-0.51	0.51	0.14	0.00	2.03	-2.03	-0.36
37	10.79	11.41	-0.62	-0.53	0.00	3.73	-3.73	-0.99	0.00	4.76	-4.76	-0.85
38	11.12	12.72	-1.60	-1.39	0.00	8.57	-8.57	-2.28	0.00	1.74	-1.74	-0.31
39	11.72	12.45	-0.73	-0.63	14.48	9.49	4.99	1.33	0.00	0.99	-0.99	-0.18
40	11.99	10.68	1.31	1.14	15.28	13.80	1.48	0.40	0.00	1.71	-1.71	-0.31
41	12.81	11.04	1.77	1.53	15.90	17.22	-1.32	-0.35	0.00	0.48	-0.48	-0.09
42	12.95	12.92	0.03	0.02	16.65	15.29	1.36	0.36	0.00	1.70	-1.70	-0.31
43	14.63	14.94	-0.31	-0.27	16.97	8.79	8.18	2.18	0.00	15.64	-15.64	-2.81
44	15.61	16.37	-0.76	-0.66	17.06	20.49	-3.43	-0.91	19.01	17.19	1.82	0.33
45	17.38	16.58	0.80	0.69	18.24	17.88	0.36	0.10	23.57	13.20	10.38	1.86
46	17.88	17.56	0.32	0.28	18.40	16.87	1.53	0.41	25.71	18.49	7.22	1.30

Table 5: Development of prediction models for fungal foliar diseases of Dr. Brent *Bt* cotton hybrid.

Hybrid : Dr.Brent *Bt*												
Standard meteorological week	Per cent disease index											
	Alternaria blight				Grey mildew				Rust			
	Observed	Predicted	Deviation	Standard Residual	Observed	Predicted	Deviation	Standard Residual	Observed	Predicted	Deviation	Standard Residual
31	4.06	5.88	-1.82	-1.51	0.00	2.04	-2.04	-0.53	0.00	-2.60	2.60	0.48
32	5.55	6.27	-0.72	-0.60	0.00	0.25	-0.25	-0.07	0.00	-1.93	1.93	0.36
33	6.08	5.94	0.14	0.12	0.00	-2.47	2.47	0.64	0.00	-2.35	2.35	0.44
34	7.10	6.82	0.28	0.23	0.00	1.50	-1.50	-0.39	0.00	-1.37	1.37	0.25
35	8.92	7.74	1.18	0.98	0.00	-0.07	0.07	0.02	0.00	-1.06	1.06	0.20
36	10.62	10.17	0.45	0.37	0.00	-0.58	0.58	0.15	0.00	1.94	-1.94	-0.36
37	10.79	10.93	-1.21	-1.01	0.00	3.83	-3.83	-1.00	0.00	4.57	-4.57	-0.85
38	11.07	12.28	1.57	1.30	0.00	8.82	-8.82	-2.30	0.00	1.69	-1.69	-0.31
39	11.42	9.85	-0.14	-0.12	14.72	9.80	4.92	1.28	0.00	0.97	-0.97	-0.18
40	12.13	12.12	0.01	0.01	15.51	14.71	-1.93	-0.50	0.00	1.69	-1.69	-0.31
41	13.39	12.79	0.60	0.49	15.78	17.71	2.10	0.55	0.00	0.49	-0.49	-0.09
42	13.20	12.89	0.31	0.26	16.29	14.19	8.24	2.15	0.00	1.65	-1.65	-0.31
43	13.77	16.85	-3.08	-2.56	16.85	20.15	0.96	0.25	0.00	15.13	-15.13	-2.80
44	15.86	15.53	0.33	0.27	17.22	8.98	0.80	0.21	18.37	16.61	1.76	0.33
45	17.06	16.02	1.04	0.87	17.83	16.28	-3.31	-0.86	22.98	12.78	10.20	1.89
46	18.00	16.92	1.08	0.89	18.93	17.97	1.55	0.40	24.74	17.87	6.87	1.27

CONCLUSIONS

The present studies concluded that, maximum and minimum temperature, morning and evening relative humidity, rainfall and rainy days are the critical weather parameters contributing to the development of alternaria blight, grey mildew and rust. Farmers are advised to take up the preventive measures to control the diseases as per the standard recommendations.

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Conflict of Interest. None.

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