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Effect of weather parameters on occurrence of fungal foliar diseases of cotton under high density and normal planting systems

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Abstract
The effect of weather factors on the development of fungal foliar diseases in LHDP-1 cotton variety was investigated during *kharif* 2018-2019. The data on per cent disease index (PDI) of Corynespora leaf spot, grey mildew and rust were recorded at three days interval under high density planting system (HDPS) and normal planting system (NPS) along with weather parameters. Correlation between progress of disease severity and weather factors was calculated and multiple regression equations with independent weather variables were derived using Excel programme to identify the critical parameters for development of diseases. Maximum temperature, morning relative humidity and evaporation accounted for 74 per cent (R^2=0.74) variation in PDI of Corynespora leaf spot under HDPS whereas minimum temperature, morning relative humidity and rainfall contributed for 79 per cent variation under NPS. In case of grey mildew evaporation in combination with rainy days and wind speed caused 71.5 per cent variation in PDI while morning relative humidity coupled with minimum temperature accounts for 88.6 per cent variation in NPS. Morning and evening relative humidity along with minimum temperature accounted for 82.9 per cent variation in rust PDI under HDPS whereas morning relative humidity, sun shine hours and wind speed contributed for75.9 per cent variation under NPS. The differences in the significant parameters indicate the role of microclimate in both planting systems.

Keywords: Corynespora leaf spot, cotton, grey mildew, high density planting system, rust, weather parameters

1. Introduction

Cotton is referred to as “King of Fibres” and also known as “White Gold”. It is one of the most important commercial crops in the state of Andhra Pradesh occupying an area of 5.24 lakh ha with a productivity of 584 kg lint/ha. In India, it occupies an area of 129.57 lakh ha with an annual production of 371 lakh bales of 170 kg and a productivity of 487kg lint/ha [1]. More than a dozen foliar diseases are reported to affect yield of seed cotton and quality of the lint [2]. Among the fungal diseases, Alternaria leaf spot/blight, grey mildew and rust cause economic losses under congenial conditions [3]. Corynespora leaf spot has been observed in Andhra Pradesh since 2017 [4]. High density planting system (HDPS) is advocated to improve the productivity in light soils under rainfed conditions by increasing the plant population and decreasing the crop duration, cost of picking besides suitability for picking. Higher plant density under narrow plant spacing (15 cm spaced plants) ensured higher seed cotton yield in all cotton genotypes and lesser CLCV infestation in MNH-886 and MNH-814 [5]. Alternaria leaf spot disease was found with significant intensity in closer spacing (2.2 lakh ha^{-1}) over wider (1.11 lakh ha^{-1}) whereas, different HDPS spacing didn’t influenced incidence of bacterial blight and grey mildew. However, higher density with closer row spacing recorded greater PDI of these diseases [6]. Keeping in view the seriousness of the fungal foliar diseases, the present study was conducted to know the effect of environmental factors on their development, under high density planting system in comparison to normal planting system.

2. Materials and Methods

Field experiment was conducted to assess the severity of fungal foliar diseases of cotton in relation to weather parameters through correlation and regression analysis during *kharif*2018-19 at RARS, Lam, Guntur. Two plots were maintained using variety LHDP-1 with two different spacings *i.e.* Normal Planting System (105 cm x 60 cm) and High Density Planting System (75 cm x 10 cm) when sown on 23.07.2018, in an area of 100 sq m each. Data on severity of fungal foliar diseases *viz.*, Corynespora leaf spot, grey mildew and rust were recorded from 15 DAS up to harvesting at three days intervals in each plot by adopting 1-4 scale [7]. Disease severity was scored in ten plants tagged randomly in each plot. The data was recorded in 10 plants tagged randomly and in each plant 10 leaves from bottom, middle and top were scored for disease by using 0-4 scale given by Shoe Raj (1988).

Weather parameters were recorded at the meteorological observatory, RARS, Lam, Guntur but for morning relative humidity which was recorded in the field with hygrometer. Means of each parameter were calculated at three days interval, whereas rainfall was totalled for three days. Correlation and multiple regression analysis were carried out between PDI [8] and weather parameters *viz*., maximum temperature (˚C), minimum temperature (˚C), morning relative humidity (%), evening relative humidity (%), rain fall (mm), sunshine hours and wind velocity (kmph) using excel programme to identify the critical parameters for development of fungal foliar diseases. Per cent Disease Index (PDI) of different fungal foliar diseases was calculated by Wheeler's formula:

$$PDI = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves scored x maximum rating}} \times 100$$

The disease index was correlated with weather data and multiple regression equations were worked out by using the formula given by [9].

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

Where, a = Intercept, b = Regression coefficient, X_1 to X_5 = Dependent weather variables

3. Results and Discussion

Corynespora leaf spot disease under HDPS first appeared on 13.12.2018 earlier to NPS with (2.5 PDI) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap were 31.1 ^{0}C, 19.5 ^{0}C, 88%, 60%, 1.2 hrs/day, 0.0 mm, 0, 4.7 kmph and 5.0 mm, respectively. The disease reached maximum at harvesting stage (27.12.2018) with PDI (8.25) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 30.3 ^{0}C, 18.3 ^{0}C, 83%, 62.6%, 4.9 hrs/day, 0.0 mm, 0, 3.5 kmph and 4.0 mm, respectively (Table 1).

Assessment of correlation coefficient (r) values revealed significant positive correlation between PDI and RH II (0.616) whereas T_{max} (-0.461), RH I (-0.742) and evap. (-0.463) were significant and negatively correlated with PDI. Rf (0.195) was non significant and positively correlated with PDI. T_{min} (-0.182), SSH (-0.176), Rd (-0.051) and WS (-0.176) were non significant and negatively correlated with PDI (Table 2).

The data on per cent disease index was subjected to multiple linear regression (MLR) and correlation with weather variables. It was observed that maximum temperature, RH I and evaporation accounted for 74 per cent (R^2=0.74) variation in PDI.

$$Y = 53.861 – 0.460 (T_{min}) – 0.467 (RH I) + 0.114 (Evap.)$$

Corynespora leaf spot disease under NPS appeared two weeks late, in comparison to HDPS, on 27.12.2018 with (2.0 PDI) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 30.3 ^{0}C, 18.3 ^{0}C, 83%, 62.6%, 4.9 hrs/day, 0.0 mm, 0, 3.5 kmph and 4.0 mm, respectively. The disease reached maximum at harvesting stage (14.01.2019) with PDI (5.0)

Table 1: Progression of cotton Corynespora leaf spot (CoLS), grey mildew and rust in relation to weather parameters under High Density Planting System (HDPS) and Normal Planting System (NPS) during *kharif* 2018-20

Date of observation	Temperature (˚C)		Relative humidity (%)		Sunshine hours (hrs/day)	Rainfall (mm)	Rainy Days	Wind Speed (kmph)	Evapo ration (mm)	Per cent Disease Index (PDI)					
										CoLS		Grey mildew		Rust	
	Max	Min	Morn.	Even.						HDPS	NPS	HDPS	NPS	HDPS	NPS
13.12.2018	31.1	19.5	88.0	60.0	1.2	0.0	0.0	4.7	5.0	2.50	0.0				
17.12.2018	29.8	18.5	86.5	72.2	2.6	31.2	1.0	8.7	3.9	4.25	0.0				
20.12.2018	25.2	17.4	88.3	76.3	1.1	36.1	1.0	10.1	2.0	5.00	0.0				
24.12.2018	29.1	16.7	86.7	65.2	5.0	0.0	0.0	2.9	2.7	6.50	0.0				
27.12.2018	30.3	18.3	83.0	62.6	4.9	0.0	0.0	3.5	4.0	8.25	2.0				
31.12.2018	28.7	14.8	87.1	67.1	4.8	2.1	0.0	2.6	3.2	5.25	2.5	1.5			
3.01.2019	29.1	13.1	92.3	61.0	9.0	0.0	0.0	4.2	4.0	6.25	3.5	1.75		2.0	
7.01.2019	29.0	15.2	88.7	61.2	4.8	0.0	0.0	3.0	3.1	5.50	3.5	2.0	1.25	2.75	1.50
10.01.2019	30.5	14.1	93.3	52.6	8.4	0.0	0.0	7.9	9.2	5.25	4.0	2.5	2.00	3.50	2.00
14.01.2019	29.7	17.2	92.2	54.0	3.9	0.0	0.0	2.1	3.8	3.75	5.0	3.5	3.25	4.00	3.75
17.1.2019	30.0	16.4	92.0	58.3	5.2	0.0	0.0	2.8	4.1	3.25	4.75	5.0	6.25	4.75	5.75
21.1.2019	30.9	17.5	93.7	54.0	5.3	0.0	0.0	4.4	4.1	3.00	4.25	3.5	3.75	3.50	3.75
24.1.2019	31.2	16.6	94.0	49.0	7.3	0.0	0.0	4.9	4.0	3.50	4.5	2.75	3.25	5.00	4.75
28.1.2019	29.6	18.9	94.7	69.7	4.9	3.9	1.0	5.8	4.4	3.25	3.5	3.25	3.75	6.25	5.50
31.1.2019	28.2	14.5	91.3	56.0	5.8	2.1	0.0	6.1	2.7	2.50	3.0	3.0	3.25	5.50	4.25
4.2.2019	29.9	15.7	91.7	47.7	7.5	0.0	0.0	3.3	3.9	2.00	2.5	2.25	2.50	4.75	4.00
7.2.2019	32.3	18.4	92.6	39.5	8.4	0.0	0.0	5.9	5.6	1.75	2.0	1.5	1.75	3.25	3.00

when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 29.7 ^{0}C, 17.2 ^{0}C, 92.2%, 54.0%, 3.9 hrs/day, 0.0 mm, 0, 2.1 kmph and 3.8 mm, respectively (Table 1).

Correlation coefficient (r) values revealed that there was significant positive correlation between PDI and RH I (0.699), SSH (0.764). T_{min} (-0.706), RH II (-0.758), Rf (-0.686), Rd (-0.623) and WS (-0.745) were significant and negatively correlated with PDI. T_{max} (0.262) was non significant and positively correlated with PDI. Evap. (-0.002) was non significant and negatively correlated with PDI (Table 2).

Multiple regression analysis revealed that minimum temperature, RH I and Rf contributed for 79 per cent (R^2=0.79) variation in PDI.

$$Y = - 11.63 - 0.061 (Rf) - 0.505 (T_{min}) + 0.252 (RH I)$$

The current results were in accordance with [10] who reported that bolls near the ground level get infected than the bolls formed at upper branches, probably due to high humidity and the presence of soil inoculum and hot and humid weather conditions for several days favouring the development of the Corynespora leaf blight of cotton disease in epidemics [11]. reported that the total rainfall above the average rainfall of past 30 years, were found to be conducive for the development of target spot in cotton.

Grey mildew disease under HDPS first appeared on 31.12.2018 with (1.5 PDI) when the corresponding T_{max}, T_{min}, RHI, RH II, SSH, Rf, Rd, WS and Evap. were 28.7˚C, 14.8˚C, 87.1%, 67.1%, 4.8 hrs/day, 2.1 mm, 0, 2.6 kmph and 3.2 mm, respectively. The disease reached maximum at harvesting stage (17.01.2019) with PDI (5.0) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 30˚C, 16.4˚C, 92%, 58.3%,5.2 hrs/day, 0.0 mm, 0, 2.8 kmph and 4.1 mm, respectively (Table 1).

Correlation coefficient (r) values indicated significant positive correlation between PDI and T_{max} (0.653), RH I (0.651) and Evap. (0.735). T_{min} (0.476), Rd (0.150) and WS (0.071) were non significant and positively correlated with PDI. RH II (-0.430), SSH (-0.257) and Rf (-0.144) were non significant and negatively correlated with PDI (Table 3).

Multiple regression analysis revealed that the evaporation in combination with Rd and WS caused 71.5 per cent (R^2=0.715) variation in PDI.

Y = - 5.832 + 3.249 (Rd) – 0.613 (WS) + 2.855 (Evap.)

Grey mildew disease under NPS appeared on 07.1.2019 *i.e.* one week later, with (1.25 PDI) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 29^{0}C, 15.2^{0}C, 88.7%, 61.2%, 4.8 hrs/day, 2.1mm, 0, 3.0 kmph and 3.1 mm, respectively. The disease reached maximum at harvesting stage (17.01.2019) with PDI (6.25) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 30 ˚C, 16.4 ˚C, 92%, 58.3%, 5.2 hrs/day, 0.0 mm, 0, 2.8 kmph and 4.1 mm, respectively (Table 1).

Correlation coefficient (r) values showed that, there is significant positive correlation between PDI and T_{max} (0.756), T_{min} (0.641), RH I (0.881) and Evap (0.747). RH II (-0.686) was significant and negatively correlated with PDI. Rf (0.021), Rd (0.352) and WS (0.344) were non significant and positively correlated with PDI. SSH (-0.209) was non significant and negatively correlated with PDI (Table 4).

Multiple regression analysis revealed that RH I coupled with T_{min} accounts for 88.6 per cent (R^2=0.886) variation in PDI (Table 5).

Y = - 50.89 + 0.564 (T_{min}) + 0.000 (RH I)

The result was in accordance with [12] minimum temperature and evaporation significantly influenced the development of grey mildew in Bt cotton hybrid, Jaadoo BG II.

Table 2: Step down regression of significant weather variables on Per cent Disease Index (PDI) of Corynespora leaf spot under High Density Planting System of Cotton during 2018-2019

Variable	Regression Co-efficient (b)	Standard error (E)	t-value
Minimum temperature	-0.460*	0.17	-2.65
Morning relative humidity	-0.467**	0.08	-5.24
Evaporation	0.114*	0.53	0.21

Y= 53.861- 0.460 (T_{min}) – 0.467 (RH I) + 0.114 (Evap.)
Intercept (a) = 53.861, (R^2) = 0.748, Fcal = 12.89
*Significant at 5% level **Significant at 1% level NS - Non Significant

Table 3: Step down regression of significant weather variables on Per cent Disease Index (PDI) of Corynespora leaf spot under Normal Planting System of cotton during *kharif* 2018-2019

Variable	Regression Co-efficient (b)	Standard error (E)	t-value
Minimum temperature	-0.505*	0.03	-1.67
Morning relative humidity	0.252**	0.15	-3.17
Rainfall	-0.061*	0.09	2.75

Y= -11.63- 0.505 (T_{min}) + 0.252 (RH I) - 0.061 (Evap.)
Intercept (a) = -11.63, (R^2) = 0.79, Fcal = 16.39
*Significant at 5% level **Significant at 1% level NS - Non Significant

Table 4: Step down regression of significant weather variables on Per cent Disease Index (PDI) of cotton grey mildew under High Density Planting System during *kharif* 2018-2019

Variable	Regression Co-efficient (b)	Standard error (E)	t-value
Rainy days	3.249*	1.75	1.85
Wind speed	-0.613*	0.27	-2.21
Evaporation	2.855**	0.64	4.39

Y= -5.832+ 3.249 (Rd) - 0.613 (WS) + 2.855 (Evap)
Intercept (a) = -5.83, (R^2) = 0.715, Fcal = 6.070
s*Significant at 5% level **Significant at 1% level NS - Non Significant

Table 5: Step down regression of significant weather variables on Per cent Disease Index (PDI) of cotton grey mildew under Normal Planting System during *kharif* 2018-2019

Variable	Regression Co-efficient (b)	Standard error (E)	t-value
Minimum temperature	0.564*	0.19	2.95
Morning relative humidity	0.000**	0.07	6.15

Y= - 50.89+ 0.564 (T_{min}) + 0.000 (RH I)
Intercept (a) = -50.89, (R^2) = 0.886, Fcal = 35.27
*Significant at 5% level **Significant at 1% level NS - Non Significant

Rust disease under HDPS first appeared on 03.1.2019 (2.0 PDI) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 29.1^{0}C, 13.1^{0}C, 92.3%, 61%, 9.0 hrs/day, 0.0 mm, 0, 4.2 kmph and 4.0 mm, respectively. The disease reached maximum at harvesting stage (28.01.2019) with PDI (6.25) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were29.6^{0}C, 18.9^{0}C, 94.7%, 69.7%,4.9 hrs/day,3.9mm,1, 5.8 kmph and 4.4 mm, respectively (Table 1).

Correlation coefficient (r) values revealed that, there is a significant positive correlation between PDI and T_{min} (0.740), RH I (0.794), Rd (0.746) whereas T_{max} (0.499), Rf (0.489), WS (0.546) and Evap (0.499) were non significant and positively correlated with PDI. RH II (-0.160) and SSH (-0.356) were non significant and negatively correlated with PDI (4.29).

Multiple regression analysis revealed that RH I and RH II along with T_{min} accounts -for 82.9 per cent (R^2=0.829) variation in PDI (Table 6).

$$Y = -55.172 + 0.415 (T_{min}) + 0.496 (RH\ I) + 0.123 (RH\ II)$$

Rust disease, under NPS first appeared on 07.1.2019 (1.5PDI), four days later, when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were 29.0°C, 15.2^{0}C, 88.7%, 61.2%,4.8 hrs/day, 0.0 mm, 0, 3.0 kmph and 3.1mm, respectively. The disease reached maximum at harvesting stage (17.01.2019) with PDI (5.75) when the corresponding T_{max}, T_{min}, RH I, RH II, SSH, Rf, Rd, WS and Evap. were30°C, 16.4°C, 92%, 58.3%,5.2 hrs/day,0.0mm,0, 2.8 kmph and 4.1 mm, respectively (Table 1).

Correlation coefficient (r) values indicated that there is a significant positive correlation between PDI and T_{min} (0.719), RH I (0.772) and WS (0.654). Rd (-0.611) was significant and negatively correlated with PDI. T_{max} (0.513), Rf (0.455) and Evap. (0.532) were non significant and positively correlated with PDI.RH II (-0.287) and SSH (-0.241) were non significant and negatively correlated with PDI (Table 6).

Multiple regression analysis revealed that RH I, SSH and WS contributedfor75.9 per cent (R^2=0.759) variation in PDI (Table 7).

$$Y = 0.523 + 0.047 (RH\ I) - 0.073 (SSH) + 0.097 (WS).$$

Sunshine hours and evaporation significantly influenced the development of rust in Bunny BG II, Jaadoo BG II and RCH 2, evaporation was significant in Narasimha, sunshine hours in L 761 and RH II significant in Bunny hybrid [13].

Table 6: Step down regression of significant weather variables on Per cent Disease Index (PDI) of cotton rust under High Density Planting System during *kharif* 2018-2019

Variable	Regression Co-efficient (b)	Standard error (E)	t-value
Minimum temperature	0.415*	0.241	1.71
Morning relative humidity	0.496*	0.152	3.24
Evening relative humidity	0.123*	0.052	2.34

Y= - 55.172+ 0.415 (T_{min}) + 0.496 (RH I) + 0.123 (RH II).

Intercept (a) = -55.172, (R^2) = 0.829, Fcal = 11.378

*Significant at 5% level **Significant at 1% level NS - Non Significant

Table 7: Step down regression of significant weather variables on Per cent Disease Index (PDI) of cotton rust under Normal Planting System during *kharif* 2018-2019

Variable	Regression Co-efficient (b)	Standard error (E)	t-value
Morning relative humidity	0.047*	0.023	2.00
Sunshine hours	-0.073*	0.058	-1.23
Wind speed	0.097*	0.044	2.16

Y= 0.523+ 0.047 (RH I) - 0.073 (SSH) + 0.097 (WS).

Intercept (a) = 0.523, (R^2) = 0.759, Fcal = 7.38

*Significant at 5% level **Significant at 1% level NS - Non Significant

Minimum temperature, morning relative humidity (RH I) and evening relative humidity (RH II) are the critical parameters contributing to the development of rust in Bt cotton hybrids [14].

5. Conclusion

The present studies showed differences in the onset of foliar diseases under HDPS and NPS. However, PDI of Corynespora leaf spot and rust were relatively more under HDPS whereas PDI of grey mildew was relatively more under NPS. Thisindicates the influence of microclimate under different planting systems which need to be explored and disease management needs to be tailored to suit HDPS.

6. Conflict of Interest: None declared

7. References

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