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Influence of sowing dates in relation to weather parameters on development of root rot disease in desi cotton (*Gossypium herbaceum* L.)

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Abstract
Cotton (*Gossypium herbaceum* L.) is a globally important crop used for both its natural fiber and seed. In Gujarat, desi cotton-growing areas are divided in to four well-defined zones among that the desi cotton grown specifically in Wagad cotton zone. Among the diseases of cotton, root rot caused by *M. phaseolina* (Tassi) Goid. is widely distributed and causing up to 90 per cent or more disease incidence infield resulting in heavy yield losses. The maximum temperature, bright sunshine hours and evaporation positively correlated with the root rot disease incidence and found to have a key role in increasing the disease incidence whereas minimum temperature, rainfall, wind speed, morning relative humidity and evening relative humidity negatively correlated with the disease incidence. The effect might be due to moisture stress condition and higher temperature coincide with the progress of disease. The significant interaction effect of year, date of sowing and varieties/ genotypes of desi cotton revealed that lowest disease incidence was recorded susceptible variety/ genotype sowing at 4th week of July. The AUDPC was found utmost in moderately resistant variety/ genotype (V2) (5840.46) sowing on 4th week of June (D1) with the rate of infection (r) 0.02 followed by susceptible variety/ genotype (V3) recorded 5131.71 and 4582.92 AUDPC with 0.03 infection rate sowing on 2nd week of July and 4th week of June, respectively.

Keywords: Desi cotton**,** *Macrophomina phaseolina*, sowing dates and rate of infection

Introduction
Cotton (*Gossypium herbaceum* L.) is a globally important crop used for both its natural fiber and seed. Cotton, "The White Gold" or the "King of Fibers" enjoys a pre-eminent status among all cash crops in the country. India ranks first followed by China, USA and Brazil in terms of cultivated area and production. In India, cotton growing areas are spread throughout the country. In Gujarat, cotton growing areas are divided in four well-define zones based on agro-climatic conditions among that the desi cotton grown specifically in Wagad cotton zone, which is spread over seven lakh hectares in six districts *viz.*, Ahmedabad, Surendranagar, Patan, Kutch, Morbi and Botad. Among the all diseases of cotton, root rot disease caused by *Macrophomina phaseolina* is widely distributed and highly destructive right from the seedling stage or after wood formation stage of crop causing up to 90 per cent or more disease incidence in field resulting in heavy yield losses. *M. phaseolina* is favoured by warm dry growing conditions and is often associated with drought stress although charcoal rot disease has been found under humid tropical conditions. A combination of water stress and high temperatures favours disease development (Mihail, 1992) [2].

Materials and Methods
The field experiments were conducted during *Kharif* 2018-19 and *Kharif* 2019-20 with three different sowing dates in sick plot maintained at Castor & Seed Spices Research Station (CSSRS), AAU, Sanand. Fifteen days interval was kept between two sowings. Weather parameters recorded at the meteorological observatory of CSSRS, AAU, Sanand was used for the present study for the entire crop seasons starting from germination to the harvesting of the crop.
The experiments were established in a factorial randomized complete block design comprising three dates of sowing (4th week of June, 2nd week of July and 4th week of July during 2018 and 2019) and three desi cotton varieties/ genotypes [1311 (Resistant), 9739-2 (Moderately resistant) and GVhv-1024 (Susceptible)]. Nine treatment combinations were assigned in three replications. The standard method was followed for other cultural practices to raise the crop.

No protection was given against any disease. Sowing at 30 cm apart, 120 cm within row spacing and plot size 4.8 × 1.5 m. Observations on the incidence of root rot was recorded at seven days interval starting from sowing to harvesting of the crop for each variety and each sowing dates. Thereafter, the root rot incidence of different treatments was correlated with the weather parameters using Karl Pearson's correlation coefficient. The following parameters were calculated in the studies:

Area under Disease Progress Curve (AUDPC) (A) value

Root rot incidence was quantified using the formula given by Wilcoxson *et al.* (1975) [7].

$$A = \sum_{i=1}^{k} ½ (Si + Si - 1) d$$

Where,
Si = Disease incidence at the end of the week
i, k = Number of successive evaluations of disease
d = Interval between two evaluations

Apparent Rate of Infection ('r')

The apparent rate of infection was calculated by using Van der Plank (1968) [6] formula:

$$r = \frac{2.303}{t2 - t1} log \frac{x2\ (1 - x1)}{x1(1 - x2)}$$

Where,
r is the apparent infection rate in non-logarithmic phase,
x1 is the disease index atinitial week time (t1),
x2 is the disease incidence at subsequent week time (t2)

Results and Discussion

Relationships of Root Rot Incidence of Three Desi Cotton Genotypes and Date of Sowing with Weather Parameters During Kharif 2018-19 and Kharif 2019-20

A study was conducted at CSSRS, AAU, Sanand during the *Kharif* 2018-19 and *Kharif* 2019-20 to assess the impact of weather parameters on the root rot incidence of desi cotton varieties. Observations for the disease incidence were recorded at weekly intervals. The correlation between the root rot incidence and concerned weather parameters (mean of maximum and minimum temperature, bright sunshine hour, Rainfall, evaporation, wind speed and relative humidity) corresponding to the meteorological weeks were determined by multiple linear regression equations. The comparative weekly observations were recorded and tabulated in Table 1 and 2.

Progressive disease development

Kharif 2018-19

The results (Table 1) revealed that disease initiated at 32nd and 34th standard meteorological week in resistant (V1), moderately resistant (V2) and susceptible variety (V3) sowing on 2nd week of July and susceptible variety (V3) sowing on 4th week of June (D1), respectively while susceptible variety (V3) sowing on 4th week of July (D3) disease was initiated at 38th standard meteorological week which progressed thereafter. The root rot was more progressive during 39th 40th and 41st standard meteorological week when the maximum temperature (35.21, 37.43 and 38.29 °C), bright sunshine (6.90, 8.17 and 7.41 hrs.) and evaporation (4.57, 5.43 and 5.43) increased, minimum temperature (23.36, 22.43 and 21.79 °C), wind speed (2.70, 1.88 and 1.78 km/hrs.), relative humidity (Rh_1) (78, 67 and 72%) and relative humidity (Rh_2) decreased (64, 55 and 47%), respectively and there was no rainfall.

The disease was initiated at 35th standard meteorological week in resistant variety (V1) sowing on 4th week of June (D1) while sowing on 4th week of July (D3) disease was initiated at 38th standard meteorological week which progressed thereafter. The root rot was more progressive during 40th and 41st standard meteorological week when the maximum temperature (37.43 and 38.29 °C) and bright sunshine (8.17 and 7.41 hrs.) increased, minimum temperature (22.43 and 21.79 °C), wind speed (1.88 and 1.78 km/hrs.) and relative humidity (Rh_2) decreased (55 and 47%), respectively and there was no rainfall.

The disease was initiated at 31st standard meteorological week in moderately resistant variety (V2) sowing on 4th week of June (D1) while sowing on 4th week of July (D3) disease was initiated at 37th standard meteorological week which progressed thereafter. The root rot was more progressive during 37th and 38st standard meteorological week when the maximum temperature (32.71 and 35.29 °C) and bright sunshine (5.09 and 5.66 hrs.) and evaporation (4.00 and 4.86) increased, wind speed (4.90 and 4.80 km/hrs.), relative humidity (Rh_1) (85 and 80%) and relative humidity (Rh_2) decreased (68 and 56%), respectively and there was no rainfall.

Kharif 2019-20

The results (Table 2) revealed that disease was initiated at 31st standard meteorological week in resistant (V1), moderately resistant (V2) and susceptible variety (V3) sowing on 4th week of June (D1) and resistant variety (V1) sowing on 2nd week of July (D2) whereas disease initiation at 32nd standard meteorological week in moderately resistant (V2) and susceptible variety (V3) sowing on 2nd week of July (D2) and resistant variety (V1) sowing on 4th week of July (D3) and disease initiation in moderately resistant (V2) and susceptible variety (V3) sowing on 4th week of July (D3) at 34th standard meteorological week which was gradually increased and progressed thereafter.

The root rot disease incidence of resistant (V1), moderately resistant (V2) and susceptible variety (V3) were not more progressive because of not much more change in responsible weather parameters *viz.*, maximum temperature, bright sunshine hours and evaporation due to the continuous rainfall and relative humidity conditions.

Hence, there was a moisture stress condition, which played an important role in disease development during the *Kharif* 2018-19 and *Kharif* 2019-20.

Correlation coefficient among disease incidence and weather parameters

The correlation coefficient among root rot incidence and weather parameters are presented in Table 3 and results presented as varieties/ genotypes and date of sowing wise as under.

Kharif 2018-19

Correlation matrix worked out (Table 3) which showed that positive and highly significant correlation (0.603) of maximum temperature with disease incidence was recorded in moderately resistant variety/ genotype (V2) sowing at 4th week of July (D3) whereas positive and significant correlation recorded in resistant variety/ genotype (V1) sowing at 4th week of June (D1) (0.544) & 4th week of July (D3) (0.582) and moderately resistant variety/ genotype (V2) sowing at 4th week of June (D1) (0.471) & 2nd week of July (D2) (0.566) and susceptible variety/ genotype (V3) sowing at 4th week of June (D1) (0.542) & 2nd week of July (D2) (0.560). A positive and non-significant correlation was recorded in resistant variety/ genotype (V1) sowing at 2nd week of July (D2) (0.400) and susceptible variety/ genotype (V3) sowing at 4th week of July (D3) (0.429).

The root rot disease incidence of all the three varieties/ genotypes with all the date of sowing were recorded negative and highly significant correlation with minimum temperature, wind speed, morning relative humidity. The root rot disease incidence of all the three varieties/ genotypes with all the dates of sowing were recorded positive and highly significant correlation with bright sunshine hours.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded positive and highly significant correlation with evaporation, except resistant variety/ genotype (V1) sowing at 2nd week of July (D2) (0.512) and susceptible variety/ genotype (V3) sowing at 4th week of July (D3) (0.530) which recorded positive and significant correlation.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded negative and highly significant correlation of disease incidence with rainfall except resistant variety/ genotype (V1) sowing at 2nd week of July (D2) (-0.524) & 4th week of July (D3) (-0.552) and susceptible variety/ genotype (V3) sowing at 4th week of July (D3) (-0.534) was recorded negative and significant correlation of disease incidence with rainfall.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded negative and highly significant correlation of disease incidence with evening relative humidity except resistant variety/ genotype (V1) sowing at 2nd week of July (D2) (-0.585) was recorded negative and significant correlation of disease incidence with evening relative humidity.

Kharif 2019-20

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded positive and non-significant correlation of disease incidence with maximum temperature whereas also recorded positive and non-significant correlation with bright sunshine hours except resistant variety (V1) sowing at 4th week of June (D1) (0.490) and susceptible variety (V3) sowing at 2nd week of July (D2) (0.479) was recorded positive and significant correlation with bright sunshine hours.

The root rot disease incidence of all the three varieties/ genotypes with all the dates of sowing were recorded negative and highly significant correlation with minimum temperature, wind speed while the positive and highly significant correlation was recorded in evaporation.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded negative and significant correlation of disease incidence with rainfall except moderately resistant variety (V2) sowing at 2nd week of July (D2) (0.592) which was recorded negative and highly significant correlation of disease incidence with rainfall.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded negative and significant correlation with morning relative humidity except resistant variety/ genotype (V1) sowing at 2nd week of July (D2) (-0.433) and moderately resistant variety/ genotype (V2) sowing at 4th week of June (D1) (-0.403) and susceptible variety/ genotype (V3) sowing at 4th week of June (D2) (-0.443) and 4th week of July (D3) (-0.432) which was recorded negative and non-significant correlation while sowing on 2nd week of July (D2) (-0.608) which was recorded negative and highly significant correlation with morning relative humidity.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded negative and non-significant correlation of evening relative humidity with disease incidence except resistant variety/ genotype (V1) sowing at 4th week of June (D1) (-0.477) & 4th week of July (D3) (-0.487) and moderately resistant variety/ genotype (V2) (-0.525) and susceptible variety/ genotype (V3) (-0.536) sowing at 2nd week of July (D2) which was recorded negative significant correlation with evening relative humidity.

Pooled (Kharif 2018-19 & 2019-20)

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded positive and highly significant correlation of disease incidence with maximum temperature except resistant variety (V1) sowing at 4th week of June (D1) (0.283) and susceptible variety (V3) sowing at 4th week of July (D3) (0.135) which was recorded positive and non-significant correlation and sowing on 4th week of June (D1) (0.403) which was recorded positive and significant correlation with maximum temperature.

The root rot disease incidence of all the three varieties/ genotypes with all the date of sowing were recorded negative and highly significant correlation with minimum temperature, wind speed and morning relative humidity.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded positive and highly significant correlation of disease incidence with bright sunshine hours except susceptible variety (V3) sowing at 4th week of July (D3) (0.392) which was recorded positive and significant correlation with bright sunshine hours.

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded positive and highly significant correlation of disease incidence with evaporation except resistant variety/ genotype (V1) sowing at 4th week of June (D1) (0.338) was recorded positive and significant correlation. A positive and non-significant correlation was recorded in susceptible variety/ genotype (V3) sowing at 4th week of July (D3) (0.306).

The data presented in Table 3 revealed that all the three

varieties/ genotypes with all the date of sowing were recorded negative and significant correlation of disease incidence with rainfall while the negative and highly significant correlation of disease incidence with rainfall was recorded in moderately resistant variety/ genotype (V2) sowing at 4th week of June (D1) (-0.431) and 2nd week of July (D2) (-0.473) whereas negative and non-significant correlation was recorded in resistant variety/ genotype (V1) sowing at 4th week of June (D1) (-0.248).

The data presented in Table 3 revealed that all the three varieties/ genotypes with all the date of sowing were recorded negative and highly significant correlation of disease incidence with evening relative humidity except resistant variety/ genotype (V1) sowing at 4th week of June (D1) (-0.358) which was recorded negative and significant correlation while the negative and non-significant correlation was recorded in susceptible variety/ genotype (V3) sowing at 4th week of July (D3) (-0.310).

Maximum temperature, bright sunshine hour and evaporation favoured the disease development. However, among all the weather parameters maximum temperature, bright sunshine hour and evaporation were found to have a key role in root rot of desi cotton disease development during *Kharif* 2018-19 and *Kharif* 2019-20.

Effect of date of sowing and desi cotton genotypes on root rot disease incidence

Kharif 2018-19

The data presented in Table 4 revealed that among the three desi cotton varieties/ genotypes minimum root rot incidence (37.31%) was recorded in resistant variety/ genotype (V1) followed by susceptible variety/ genotype (V3) (53.25%) and moderately resistant variety/ genotype (V2) (53.25%).

Among the three dates of sowing minimum root rot incidence was recorded in sowing at 4th week of July (D3) (33.86%) followed by sowing at 2nd week of July (D2) (56.98%) at par with sowing at 4th week of June (D1) (61.54%).

The interaction effect of date of sowing and varieties/ genotypes of desi cotton presented in Table 4 revealed that minimum root rot disease incidence (15.91%) was recorded in susceptible variety/ genotype (V3) sowing at 4th week of July (D3) followed by resistant variety/genotype (V1) sowing at all three dates of sowing *i.e.* 4th week of June (D1) (34.76%), 2nd week of July (D2) (37.72%) and 4th week of July (D3) (39.46%) while the highest root rot incidence was recorded in moderately resistant variety/ genotype (V2) sowing at 4th week of June (D1) (84.31%) followed by susceptible variety/ genotype (V3) sowing at 2nd week of July (D2) (78.29%).

Kharif 2019-20

The data presented in Table 4 revealed that among the three desi cotton varieties/ genotypes minimum root rot incidence (30.37%) was recorded in resistant variety/ genotype (V1) followed by moderately resistant variety/ genotype (V2) (45.13%) at par with susceptible variety/ genotype (V3) (45.34%).

Among all three dates of sowing minimum root rot incidence was recorded in sowing at 4th week of July (D3) (25.17%) followed by sowing at 2nd week of July (D2) (39.08%) and sowing at 4th week of June (D1) (56.59%).

The interaction effect of date of sowing and varieties/ genotypes of desi cotton presented in Table 4 revealed that minimum root rot incidence (24.44%) was recorded in resistant variety/ genotype (V1) sowing at 4th week of July (D3) at par with susceptible variety/ genotype (V3) (24.57%) and moderately resistant variety/ genotype (V2) (26.49%) sowing at 4th week of July (D3) and resistant variety/ genotype (V1) sowing at 2nd week of July (28.90%). The highest root rot incidence (66.44%) was recorded in susceptible variety/genotype (V3) and moderately resistant variety/ genotype (V2) (65.56%) sowing at 4th week of June (D1). Early sowing (D1) (4th week of June) of the resistant (V1), moderately resistant (V2) and susceptible variety/ genotype (V3) were recorded more root rot incidence compare to sowing at 2nd and 4th week of July (D1 & D2).

Pooled (Kharif: 2018-19 & 2019-20)

The data presented in Table 4 revealed that among the three desi cotton varieties/ genotypes minimum root rot incidence (33.84%) was recorded in resistant variety/ genotype (V1) followed by moderately resistant variety/ genotype (V2) (53.47%) at par with susceptible variety/ genotype (V3) (49.29%).

Among all three dates of sowing minimum root rot incidence was recorded in sowing at 4th week of July (D3) (29.51%) followed by sowing at 2nd week of July (D2) (48.03%) and sowing at 4th week of June (D1) (59.07%).

The significant interaction effect of year, date of sowing and varieties/ genotypes of desi cotton presented in Table 4 revealed that minimum root rot incidence (20.24%) was recorded in susceptible variety/ genotype (V3) sowing at 4th week of July (D3) followed by resistant variety/ genotype (V1) (31.95%) sowing at 4th week of July (D3) and same variety/ genotype sowing at 2nd week of July (D2) (33.31%) and sowing at 4th week of June (D1) (36.27%) whereas moderately susceptible variety/ genotype (V2) recorded the lowest root rot incidence sowing at 4th week of July (D3) (36.35%) while the highest root rot incidence was recorded in same variety/ genotype sowing at 4th week of June (D1) (74.93%) followed by susceptible variety/ genotype (V3) sowing at 4th week of June (D1) (66.00%) and sowing at 2nd week of July (D2) (61.64%). Early sowing (D1) (4th week of June) of the resistant (V1), moderately resistant (V2) and susceptible variety/ genotype (V3) were recorded more root rot incidence compare to sowing at 2nd and 4th week of July (D2 & D3).

The pooled results revealed the lowest root rot disease incidence was found in late sowing of any variety/genotype of desi cotton might be due to the susceptible stage of the crop was escaped which favor the root rot disease.

Root Rot Incidence of Different Treatments Correlated with The Weather Parameters Using Karl Pearson's Correlation Coefficient

AUDPC ('A' value) and apparent rate of infection ('r' value) (Kharif 2018-19)

AUDPC was found utmost in moderately resistant variety/ genotype (V2) sowing on 4th week of June (D1) (7120.95) with the rate of infection 0.02 followed by susceptible variety/ genotype (V3) sowing on 2nd week of July sowing (D2) (5572.43) with 0.03 rate of infection, susceptible variety/ genotype (V3) sowing on 4th week of June (D1) sowing was

recorded 4474.84 AUDPC with 0.02 rate of infection, moderately resistant variety/ genotype (V2) sowing on 2nd week of July sowing (D2) & 4th week of July (D3) were recorded 4076.14 and 2968.59 AUDPC with an infection rate of 0.03 and 0.02, respectively. Resistant variety/ genotype (V1) sowing on 2nd week of July sowing (D2) & 4th week of June (D1) were recorded 2944.97 and 2062.27 AUDPC with rate of infection 0.01 and 0.02, respectively. The lowest AUDPC (778.86) was recorded in susceptible variety/ genotype (V3) sowing on 4th week of July (D3) sowing with an infection rate of 0.01 (Fig. 1).

AUDPC ('A' value) and apparent rate of infection ('r' value) (Kharif 2019-20)

AUDPC was found utmost on susceptible variety/ genotype (V3) sowing on 4th week of June & 2nd week of July (4691.00) with the rate of infection 0.02 followed by moderately resistant variety/ genotype (V2) and resistant variety/ genotype (V1) sowing on 4th week of June (D1) was recorded 4559.97 and 3066.86 AUDPC with 0.01 rate of infection. Moderately resistant (V2) and resistant variety/ genotype (V1) were recorded 2739.52 and 2123.08 AUDPC with 0.03 and 0.01 infection rates, respectively sowing on 2nd week of July (D2). Resistant (V1) and susceptible variety/ genotype (V3) were recorded 1466.90 and 1244.04 AUDPC with 0.02 and 0.03 infection rates, respectively sowing on 4th week of July (D3) (Fig. 1).

AUDPC ('A' value) and apparent rate of infection ('r' value) (Pooled 2018-19 & 2019-20)

AUDPC was found utmost in moderately resistant variety/ genotype (V2) (5840.46) sowing on 4th week of June (D1) with the rate of infection 0.02 followed by susceptible variety/ genotype (V3) recorded 5131.71 and 4582.92 AUDPC with 0.03 infection rate sowing on 2nd week of July and 4th week of June, respectively. Moderately resistant variety/ genotype was recorded 3407.83 AUDPC sowing on 2nd week of July with 0.03 infection rate. Resistant variety recorded 2564.57 and 2534.02 AUDPC with 0.02 infection sowing on 4th week of June and 2nd week of July, respectively. Resistant (V1) and moderately resistant variety/ genotype (V2) were recorded 1951.97 and 2367.15 AUDPC with 0.02 infection rate and susceptible variety/ genotype (V3) was recorded lowest AUDPC (1011.45) with 0.03 infection rate on 4th week of July (D3) date of sowing (Fig. 1).The pooled data revealed that lowest AUDPC was recorded in resistant, moderately resistant and susceptible variety sowing at 4th week of July.

Development of forewarning model for root rot disease of desi cotton

The standard week wise data of average root rot incidence of three different desi cotton genotypes sowing at three different dates of sowing and weather parameters were subjected to regression analysis by using full regression model and stepwise regression model method for the selection of most appropriate variables to develop forewarning models. The results obtained using regression analysis are presented in Table 5 to 10 and forewarning models developed for different genotypes and dates of sowing are discussed as under (Fig. 2 to 4).

The results presented in Table 6 revealed that the coefficient of determination (R^2) value indicated the proportion of total variation in output explained by the independent variables. The R^2 value obtained above 0.77 which showed that wind speed, evening relative humidity, rainfall and maximum temperature and morning relative humidity was negatively correlated. These weather parameters contributed >77 per cent key role for the development of the root rot disease incidence of desi cotton during *Kharif* 2018-19.

The results presented in Table 8 revealed that the R^2 value obtained above 0.81, which showed that wind speed and minimum temperature was negatively correlated while the bright sunshine hours, evaporation and evening relative humidity was positively correlated which was indicated that these weather parameters contributed >81 per cent key role for the development of the root rot disease incidence of desi cotton during *Kharif* 2019-20.

The pooled results of *Kharif* 2018-19 & 2019-20 presented in Table 10 revealed that the R^2 value obtained above 0.74, which showed that wind speed, minimum temperature and evening relative humidity was negatively correlated while the maximum temperature, bright sunshine hours and evaporation was positively correlated which was indicated that these parameters contributed >74 per cent and played a key role for the development of the root rot disease incidence of desi cotton.

The pooled results revealed that among all the weather parameters maximum temperature, bright sunshine hours and evaporation positively correlate with the root rot disease incidence and found to have a key role in increasing the root rot incidence whereas minimum temperature, rainfall, wind speed, morning relative humidity and evening relative humidity negatively correlated with the root rot disease incidence during the *Kharif* 2018-19 and *Kharif* 2019-20. In nutshell, it is inferred that disease incidence was increased with progressive rise in maximum temperature, bright sunshine hours and evaporation and decreased in minimum temperature, wind speed and relative humidity and there was no rainfall.

A similar type of the results were also recorded by Sharma *et al*. (2001) [5], Arora and Pareek (2013) [1], Satpathi (2017) [4] and Partridge Darcy (2017) [3] they recorded that maximum temperature, bright sunshine hours and water stress condition which favours the root rot disease development.

Table 1: Correlation of disease incidence of root rot in desi cotton with weather parameters (*Kharif:* 2018-19)

SMW	Disease incidence (%)									Weather parameters							
	V1D1	V1D2	V1D3	V2D1	V2D2	V2D3	V3D1	V3D2	V3D3	Atmospheric Temperature (°C)		BSS (hr)	Rainfall (mm)	Evaporation	WS (km/hr)	Relative humidity (%)	
										Max.	Min.					Rh_1	Rh_2
26th	0.00	-	-	0.00	-	-	0.00	-	-	39.64	27.07	2.99	1.50	5.29	10.10	54	67
27th	0.00	-	-	0.00	-	-	0.00	-	-	35.40	27.09	1.20	2.50	4.60	10.30	91	75
28th	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	32.60	27.01	0.30	4.50	3.90	6.80	84	74
29th	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	30.90	26.20	0.10	6.20	1.70	6.70	92	76
30th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.90	26.20	0.00	0.00	4.00	8.60	71	93
31st	0.00	0.00	0.00	6.74	0.00	0.00	0.00	0.00	0.00	35.40	26.90	0.00	0.00	4.60	10.30	79	61
32nd	0.00	6.79	0.00	15.14	1.74	0.00	0.00	3.33	0.00	33.40	25.90	2.23	28.00	2.30	9.00	82	61
33rd	0.00	13.66	0.00	25.54	3.48	0.00	0.00	6.67	0.00	34.10	26.10	2.23	48.00	0.60	6.40	72	60
34th	0.00	17.28	0.00	28.50	5.56	0.00	5.16	10.00	0.00	30.10	25.20	0.00	46.00	0.00	5.70	92	82
35th	2.38	19.19	0.00	31.76	7.22	0.00	8.89	11.96	0.00	30.40	25.20	1.54	17.00	0.30	7.60	92	83
36th	5.71	20.10	0.00	39.42	15.15	0.00	10.04	13.58	0.00	30.36	24.29	2.86	1.00	3.14	5.20	88	83
37th	12.38	21.27	0.00	53.45	21.93	3.50	21.71	26.82	0.00	32.71	24.93	5.09	0.00	4.00	4.90	85	68
38th	15.71	21.27	5.11	66.03	31.61	19.32	30.00	35.41	4.60	35.29	25.14	5.66	0.00	4.86	4.80	80	56
39th	17.38	26.82	20.18	68.02	41.74	25.25	36.72	46.80	4.60	35.21	23.36	6.90	0.00	4.57	2.70	78	64
40th	23.42	33.33	26.93	71.82	47.04	34.92	50.08	60.43	5.64	37.43	22.43	8.17	0.00	5.43	1.88	67	55
41st	31.43	35.64	39.46	75.69	52.36	43.18	58.89	75.91	9.07	38.29	21.79	7.41	0.00	5.43	1.78	72	47
42nd	31.43	35.64	39.46	75.69	52.37	44.16	58.89	75.91	10.13	37.64	20.57	8.89	0.00	6.00	1.89	67	43
43rd	33.10	37.72	39.46	80.07	54.93	45.80	63.89	76.92	13.53	36.71	17.57	9.66	0.00	6.29	2.12	36	48
44th	34.76	37.72	39.46	84.31	54.93	46.21	65.56	78.29	13.53	35.93	18.57	8.89	0.00	5.14	2.14	37	49
45th	34.76	37.72	39.46	84.31	54.93	46.21	65.56	78.29	13.53	36.00	27.00	8.31	0.00	5.43	2.33	52	56
46th	34.76	37.72	39.46	84.31	54.93	46.21	65.56	78.29	13.53	34.93	19.43	7.60	0.00	4.00	1.20	75	53
47th	34.76	37.72	39.46	84.31	54.93	46.21	65.56	78.29	15.14	34.50	20.43	4.66	0.00	3.43	1.85	67	51
48th	34.76	37.72	39.46	84.31	54.93	46.21	65.56	78.29	15.91	31.00	15.36	6.27	0.00	2.86	2.76	66	50

Rh_1: Relative humidity (Morning), Rh_2: Relative humidity (Evening)

SMW: Standard Meteorological Week, BSS **:**Bright sunshine hour, WS **:**Wind speed

Table 2: Correlation of disease incidence of root rot in desi cotton with weather parameters (*Kharif:* 2019-20)

SMW	Disease incidence (%)									Weather parameters							
	V1D1	V1D2	V1D3	V2D1	V2D2	V2D3	V3D1	V3D2	V3D3	Atmospheric Temperature (°C)		BSS (hr)	Rainfall (mm)	Evaporation	WS (km/hr)	Relative humidity (%)	
										Max.	Min.					Rh_1	Rh_2
26th	0.00			0.00			0.00			38.71	26.29	4.31	16.00	2.29	10.10	92	74
27th	0.00			0.00			0.00			35.21	26.36	1.66	0.00	4.29	7.01	93	75
28th	0.00	0.00		0.00	0.00		0.00	0.00		38.21	27.07	3.47	0.00	6.86	6.18	76	48
29th	0.00	0.00		0.00	0.00		0.00	0.00		37.07	25.71	5.70	0.00	7.71	1.25	84	51
30th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.00	26.07	2.37	26.00	4.00	8.00	74	86
31st	9.33	4.55	0.00	11.85	0.00	0.00	5.22	0.00	0.00	30.50	24.79	0.00	101.00	0.00	6.92	90	82
32nd	17.04	8.44	3.33	20.94	1.78	0.00	16.67	8.33	0.00	29.93	25.21	1.33	230.00	0.00	7.42	91	85
33rd	17.78	8.78	3.33	23.67	7.06	0.00	22.44	10.66	0.00	31.93	23.79	2.19	14.00	0.00	4.90	89	71
34th	20.53	10.77	7.33	26.63	9.95	5.33	23.33	12.74	1.00	32.93	25.36	3.37	3.00	1.14	4.05	85	63
35th	22.07	15.10	7.33	28.94	11.66	7.55	28.52	15.44	2.10	32.50	25.50	6.20	20.00	1.43	5.90	89	83
36th	22.70	17.26	8.00	31.93	13.33	10.71	30.11	17.89	5.10	32.50	24.50	3.70	216.00	0.00	2.86	89	83
37th	25.91	19.35	8.89	33.00	17.00	13.94	34.58	22.33	9.56	32.36	25.14	1.19	44.00	0.00	2.79	92	86
38th	27.41	20.52	8.89	36.23	21.11	14.36	37.73	23.33	9.56	33.14	25.00	5.17	0.00	3.71	3.18	85	74
39th	27.41	20.52	8.89	36.94	21.11	14.36	39.39	23.33	9.56	32.00	24.00	2.94	44.00	1.14	4.66	89	80
40th	29.07	20.52	10.67	38.61	25.00	16.68	39.39	29.11	10.23	32.93	22.29	6.13	12.00	0.00	3.85	85	82
41st	30.74	20.52	13.89	40.72	27.56	18.34	41.78	32.45	10.90	34.93	22.00	3.76	0.00	0.57	1.58	75	71
42nd	30.74	20.52	13.89	41.39	30.56	19.15	41.78	35.56	11.20	34.57	21.14	5.17	0.00	4.00	1.88	71	59
43rd	32.41	22.19	15.22	42.22	32.22	20.34	45.37	38.32	13.20	32.07	18.29	4.94	0.00	3.71	3.93	45	51
44th	34.11	24.65	19.33	43.89	33.89	21.57	50.40	39.66	16.89	34.20	21.36	4.27	21.00	3.14	2.01	56	65
45th	35.33	26.31	20.44	48.89	36.78	24.23	55.22	40.56	19.57	34.15	20.50	6.26	0.00	1.71	1.10	80	73
46th	36.67	28.65	23.44	52.22	38.79	25.94	60.00	41.56	21.99	32.07	19.43	6.31	0.00	3.14	1.88	80	70
47th	37.78	29.31	24.44	60.56	41.89	26.49	65.00	41.67	24.57	31.79	18.36	1.90	0.00	2.00	1.03	77	64
48th	37.78	29.57	24.44	65.56	43.33	26.49	66.44	45.00	24.57	30.21	16.57	2.41	0.00	3.43	1.20	83	73

Rh_1: Relative humidity (Morning), Rh_2: Relative humidity (Evening)

SMW: Standard Meteorological Week, BSS**:** Bright sunshine hour, WS**:** Wind speed

Table 3: Correlation of date of sowing and varieties/genotypes of desi cotton with weather parameters (*Kharif*: 2018-19 & *Kharif*: 2019-20)

Treat. Combination	Max. Temperature (°C)			Min. Temperature (°C)			BSS (hr)			Evaporation		
	Kharif 2018-19	*Kharif* 2019-20	Pooled	*Kharif* 2018-19	*Kharif* 2019-20	Pooled	*Kharif* 2018-19	*Kharif* 2019-20	Pooled	*Kharif* 2018-19	*Kharif* 2019-20	Pooled
V1D1	0.544*	0.358	0.283	-0.750**	-0.814**	-0.731**	0.878**	0.490*	0.600**	0.669**	0.654**	0.338*
V1D2	0.400	0.286	0.464**	-0.742**	-0.780**	-0.677**	0.858**	0.455	0.773**	0.512*	0.623**	0.618**
V1D3	0.582*	0.221	0.565**	-0.753**	-0.878**	-0.698**	0.835**	0.376	0.755**	0.622**	0.638**	0.635**
V2D1	0.471*	0.168	0.520**	-0.709**	-0.868**	-0.629**	0.896**	0.344	0.784**	0.622**	0.619**	0.700**
V2D2	0.566*	0.314	0.559**	-0.737**	-0.885**	-0.725**	0.911**	0.439	0.802**	0.693**	0.685**	0.708**
V2D3	0.603**	0.344	0.605**	-0.745**	-0.825**	-0.681**	0.869**	0.455	0.794**	0.663**	0.649**	0.674**
V3D1	0.542*	0.234	0.403*	-0.753**	-0.846**	-0.776**	0.882**	0.407	0.705**	0.658**	0.631**	0.520**
V3D2	0.560*	0.363	0.598**	-0.752**	-0.869**	-0.668**	0.887**	0.479*	0.814**	0.651**	0.683**	0.700**
V3D3	0.429	0.149	0.135	-0.779**	-0.868**	-0.790**	0.759**	0.290	0.392*	0.530*	0.609**	0.306
Treat. Combination	**Rainfall (mm)**			**Wind Speed (km/hr)**			**Rh_1 (%)**			**Rh_2 (%)**		
	Kharif 2018-19	*Kharif* 2019-20	Pooled	*Kharif* 2018-19	*Kharif* 2019-20	Pooled	*Kharif* 2018-19	*Kharif* 2019-20	Pooled	*Kharif* 2018-19	*Kharif* 2019-20	Pooled
V1D1	-0.655**	-0.560*	-0.248	-0.895**	-0.863**	-0.871**	-0.721**	-0.527*	-0.484**	-0.767**	-0.477*	-0.358*
V1D2	-0.524*	-0.501*	-0.420*	-0.961**	-0.854**	-0.802**	-0.635**	-0.433	-0.612**	-0.585*	-0.355	-0.587**
V1D3	-0.552*	-0.508*	-0.354*	-0.860**	-0.845**	-0.744**	-0.742**	-0.498*	-0.687**	-0.786**	-0.487*	-0.704**
V2D1	-0.637**	-0.512*	-0.431**	-0.952**	-0.846**	-0.734**	-0.634**	-0.403	-0.613**	-0.656**	-0.419	-0.674**
V2D2	-0.668**	-0.592**	-0.473**	-0.937**	-0.864**	-0.816**	-0.691**	-0.556*	-0.675**	-0.737**	-0.525*	-0.691**
V2D3	-0.596**	-0.542*	-0.389*	-0.880**	-0.873**	-0.760**	-0.742**	-0.520*	-0.696**	-0.806**	-0.443	-0.716**
V3D1	-0.642**	-0.541*	-0.364*	-0.908**	-0.854**	-0.883**	-0.717**	-0.443	-0.583**	-0.748**	-0.430	-0.521**
V3D2	-0.613**	-0.559*	-0.410*	-0.918**	-0.858**	-0.744**	-0.713**	-0.608**	-0.702**	-0.760**	-0.536*	-0.734**
V3D3	-0.534*	-0.490*	-0.338*	-0.797**	-0.830**	-0.782**	-0.750**	-0.432	-0.442**	-0.751**	-0.390	-0.310
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

Rh_1: Relative humidity (Morning), Rh_2: Relative humidity (Evening), BSS*:* Bright sunshine hour, WS: Wind speed

Table 4: Effect of date of sowing and desi cotton varieties/genotypes on root rot disease incidence

Treatments	Root rot incidence (%)					
	2018-19		2019-20		Pooled	
Variety/ genotype (V)						
V1	37.31		30.37		33.84	
V2	61.82		45.13		53.47	
V3	53.25		45.34		49.29	
S.Em.±	1.85		1.65		2.69	
C.D. at 5%	5.56		4.95		NS	
Date of Sowing (D)						
D1	61.54		56.59		59.07	
D2	56.98		39.08		48.03	
D3	33.86		25.17		29.51	
S.Em.±	1.85		1.65		3.33	
C.D. at 5%	5.56		4.95		20.28	
Interaction (V x D)						
V1D1	34.76		37.77		36.27	
V1D2	37.72		28.90		33.31	
V1D3	39.46		24.44		31.95	
V2D1	84.31		65.56		74.93	
V2D2	54.93		43.33		49.13	
V2D3	46.21		26.49		36.35	
V3D1	65.56		66.44		66.00	
V3D2	78.29		45.00		61.64	
V3D3	15.91		24.57		20.24	
	S. Em. ±	C.D. at 5%	S. Em. ±	C.D. at 5%	S. Em. ±	C.D. at 5%
Year (Y)	-	-	-	-	1.01	2.92
YxV	-	-	-	-	1.75	5.06
YxD	-	-	-	-	1.75	5.06
VxD	3.21	9.62	2.86	8.57	7.65	NS
YxVxD	-	-	-	-	3.04	8.76
C.V. %	10.94		12.29		11.56	

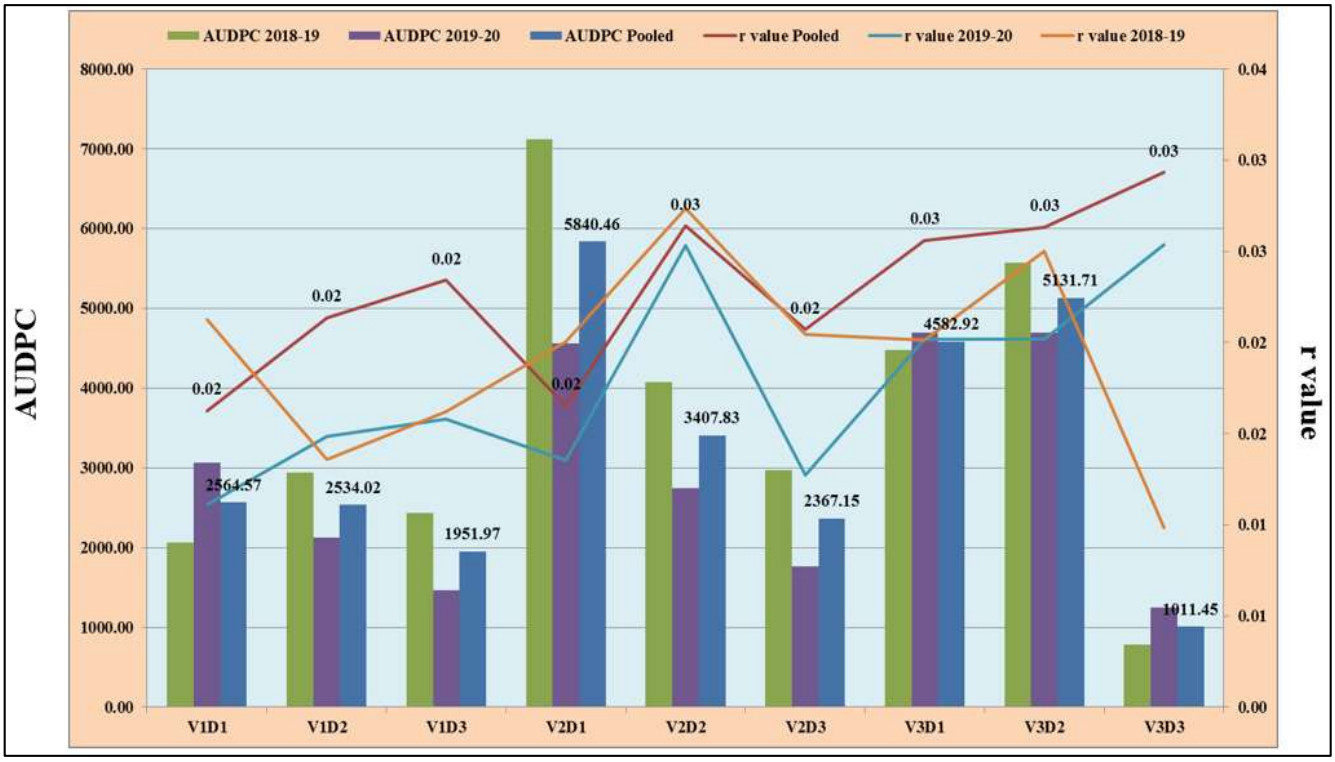


Fig 1: AUDPC and r value of different varieties/ genotypes and date of sowing against root rot disease incidence

Table 5: Full regression model for individual treatments (*Kharif*: 2018-19)

Treatments	Constant	Weather parameters								R^2
		Max. Temp.	Min. Temp.	BSS	Rainfall (RF)	Evaporation (EV)	Wind speed (WS)	Rh_1	Rh_2	
V1D1	119.68	0.99	0.49	-0.26	-0.40*	-2.26	-3.40**	-0.23*	-0.56**	0.97
V1D2	65.02	-0.06	0.08	0.74	-0.24*	-3.03	-3.34**	-0.16*	-0.06	0.97
V1D3	85.82	1.17	-0.41	-1.23	-0.41	3.87	-4.14**	-0.36	0.48	0.92
V2D1	209.74	-2.49	1.53*	1.89	-0.64**	-4.42	-7.09**	-0.22	-0.73*	0.98
V2D2	124.40	-0.49	0.33	0.31	-0.50**	-2.67	-5.37**	-0.22	-0.52*	0.98
V2D3	116.93	0.40	0.09	-0.77	-0.48	-3.86	-4.63**	-0.34	-0.70	0.95
V3D1	179.89	-0.64	0.48	-0.30	-0.74*	-5.10	-6.37**	-0.44*	-0.79	0.97
V3D2	193.62	-0.30	0.36	-0.17	-0.72*	-5.64	-7.60**	-0.43	-0.93*	0.97
V3D3	79.20	-0.80	0.21	-0.66	-0.18	-1.31	-1.49*	-0.19*	-0.34*	0.94

Table 6: Stepwise regression model for individual treatments (*Kharif*: 2018-19)

Treatments	Constant	Weather parameters					R^2
		Max. Temp.	Rainfall (RF)	Wind speed (WS)	Rh_1	Rh_2	
V1D1	120.33	-1.441*	-0.216**	-3.229**	-	-0.613**	0.95
V1D2	43.95	-	-	-4.209**	-		0.92
V1D3	77.07	-	-	-4.20**	-	-0.66**	0.86
V2D1	96.00	-	-0.36**	-8.29**	-		0.94
V2D2	85.92	-	-0.30**	-5.68**	-	-0.44**	0.97
V2D3	90.28	-	-	-4.83**	-	-0.76**	0.91
V3D1	104.74	-	-0.32*	-6.47**	-	-0.64**	0.92
V3D2	134.42	-	-	-8.43**	-	-0.89**	0.92
V3D3	24.14	-	-	-1.27**	-0.17**	-	0.77

Table 7: Full regression model for individual treatments (*Kharif*: 2019-20)

Treatments	Constant	Weather parameters								R^2
		Max. Temp.	Min. Temp.	BSS	Rainfall (RF)	Evaporation (EV)	Wind speed (WS)	Rh_1	Rh_2	
V1D1	83.99	-1.24	-0.58	0.93	-0.01	0.45	-2.74*	-0.19	0.24	0.92
V1D2	85.50	-1.96	-0.20	0.92	-0.02	0.71	-3.16**	-0.22	0.36*	0.94
V1D3	81.10	-1.35	-0.96	0.63	0.00	0.36	-2.43*	-0.09	0.12	0.93
V2D1	155.46	-2.57	-1.88	0.97	-0.02	1.15	-4.43*	-0.03	0.28	0.94
V2D2	78.72	-0.35	-2.32*	0.66	-0.02	1.39	-3.11*	-0.17	0.39*	0.97
V2D3	58.02	-0.79	-0.96	0.62	-0.02	0.93	-2.91*	-0.23	0.40*	0.95
V3D1	196.82	-3.82	-1.51	1.72	-0.03	1.00	-6.02*	-0.24	0.45	0.94
V3D2	77.95	-0.15	-2.13*	0.93	-0.01	1.13	-3.17*	-0.30	0.43	0.97
V3D3	76.00	-1.42	-1.16	0.12	-0.02	0.95	-2.67*	-0.15	0.36*	0.94

Table 8: Stepwise regression model for individual treatments (*Kharif*: 2019-20)

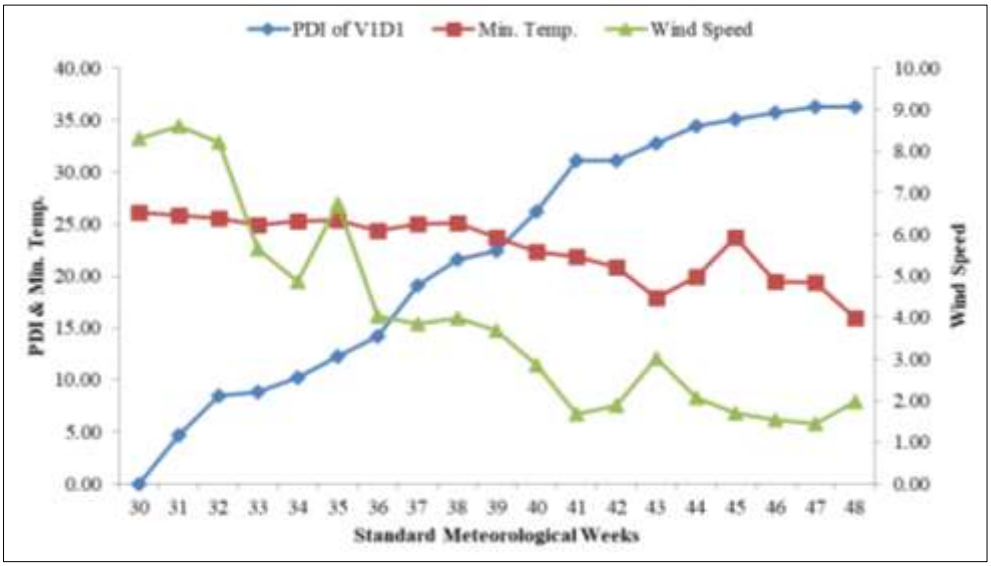
Treatments	Constant	Weather parameters					R^2
		Max. Temp.	Rainfall (RF)	Wind speed (WS)	Rh_1	Rh_2	
V1D1	58.31	-1.22**	0.91*	-	-2.02**	-	0.89
V1D2	49.06	-0.99*	-	-	-2.26**	-	0.81
V1D3	52.03	-1.50**	-	-	-1.79**	-	0.89
V2D1	107.59	-2.60**	-	-	-3.32**	-	0.88
V2D2	88.93	-2.68**	1.16*	-	-3.02**	-	0.94
V2D3	55.39	-1.41**	-	-	-2.70**	-	0.87
V3D1	119.26	-2.91**	-	-	-4.41**	-	0.87
V3D2	88.66	-2.57**	1.48*	-	-2.94**	-	0.94
V3D3	34.79	-1.87**	-	1.34*	-1.86**	0.30**	0.93

Table 9: Full regression model for individual treatments (Pooled: *Kharif* 2018-19 & *Kharif* 2019-20)

Treatments	Constant	Weather parameters								R^2
		Max. Temp.	Min. Temp.	BSS	Rainfall (RF)	Evaporation (EV)	Wind speed (WS)	Rh_1	Rh_2	
V1D1	60.82	-0.09	-1.03	0.64	0.01	-0.22	-3.30**	-0.11	0.10	0.81
V1D2	74.24	-1.12	-0.15	1.34*	-0.00	0.99	-2.20**	-0.03	-0.13	0.83
V1D3	56.68	0.32	-1.16	1.15	0.03	0.47	-2.04*	-0.03	-0.33	0.83
V2D1	180.38	-3.21	0.13	3.12*	0.02	3.40	-4.40**	0.15	-0.70	0.83
V2D2	89.00	-0.59	-1.09	1.54*	3.97	2.40*	-3.53**	0.00	-0.25	0.92
V2D3	53.60	0.42	-1.09	1.51	0.03	0.86	-2.46*	-0.03	-0.33	0.86
V3D1	115.48	-0.50	-1.91*	1.32	0.02	1.34	-5.30**	-0.08	-0.02	0.89
V3D2	129.28	-0.87	-1.01	3.08*	0.04	1.74	-3.84**	-0.03	-0.67	0.87
V3D3	38.12	0.07	-1.15*	-0.79	-0.01	0.61	-1.78**	-0.10	0.16	0.79

Table 10: Stepwise regression model for individual treatments (Pooled: *Kharif* 2018-19 & *Kharif* 2019-20)

Treatments	Constant	Weather parameters						R^2
		Max. Temp.	Min. Temp.	BSS	Evaporation (EV)	Wind speed (WS)	Rh_2	
V1D1	60.10	-	-1.06*	-	-	-3.61**	-	0.80
V1D2	28.69	-	-	-	1.95**	-2.93**	-	0.77
V1D3	0.074	1.98*	-2.54**	1.67*	-	-	-	0.78
V2D1	44.08	-	-	2.17	4.16**	-4.44**	-	0.78
V2D2	60.34	-	-1.55**	1.50*	3.08**	-3.22**	-	0.91
V2D3	-7.03	2.31**	-2.69**	2.25**	-	-	-	0.81
V3D1	99.46	-	-2.31**	2.03**	-	-4.84**	-	0.88
V3D2	91.35	-	-	3.09**	-	-4.52**	-0.78**	0.85
V3D3	40.47	-	-1.17**	-	-	-1.46**	-	0.74



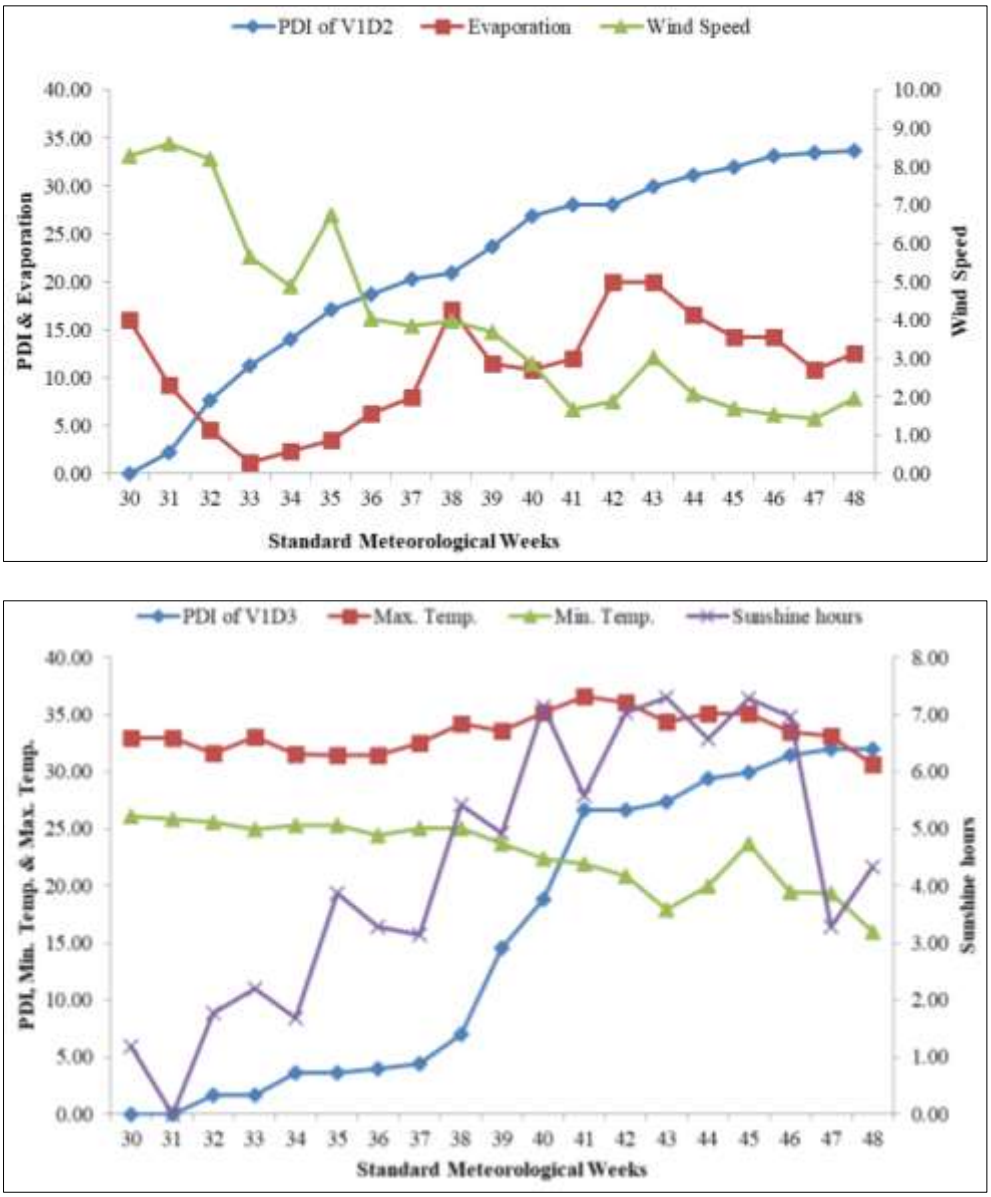
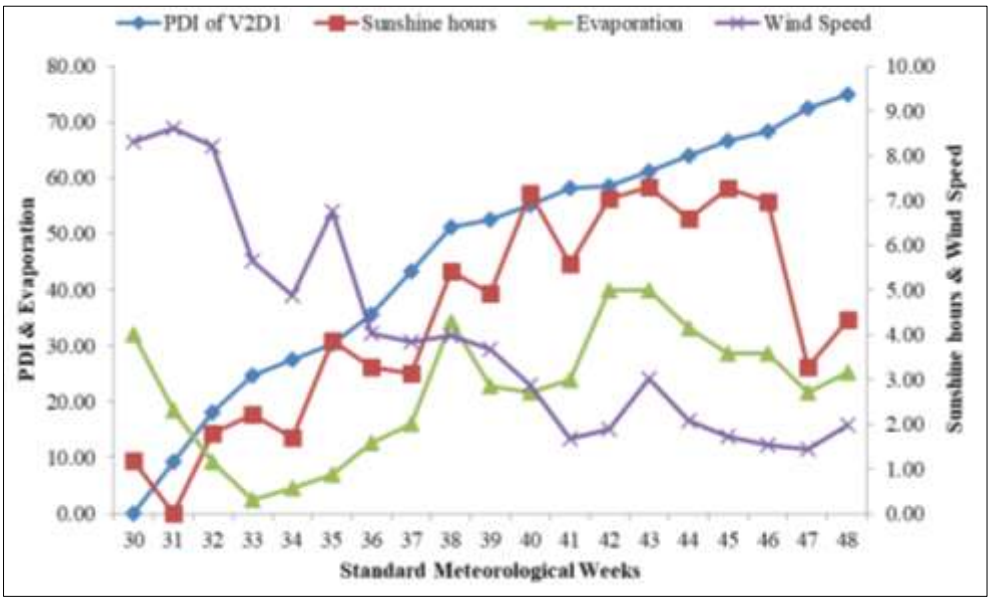


Fig 2: Stepwise regression model for resistant variety/ genotype (V1) of desi cotton and sowing dates (D1, D2 & D3) against root rot disease incidence and weather parameters (Pooled: 2018-19 & 2019-20)



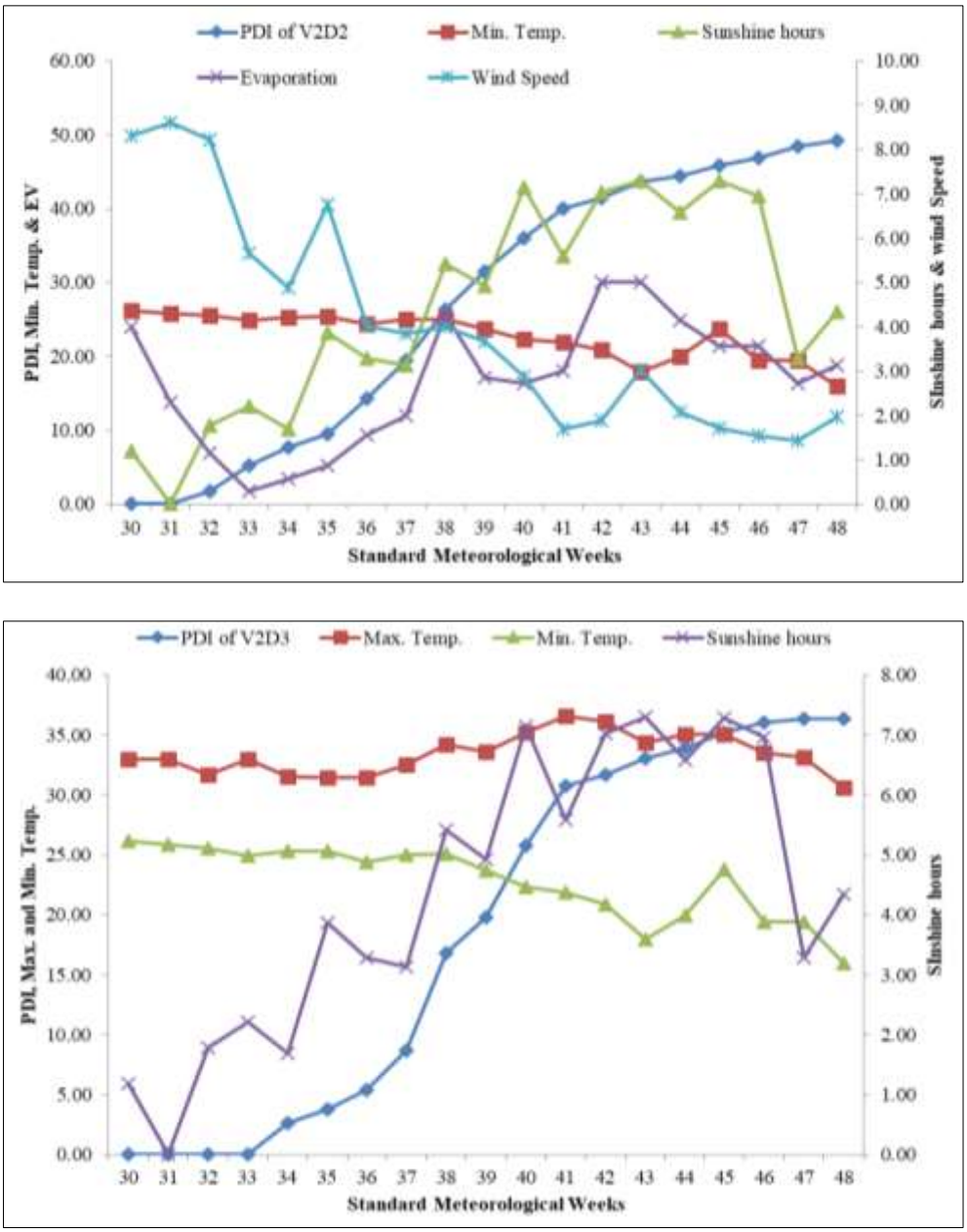
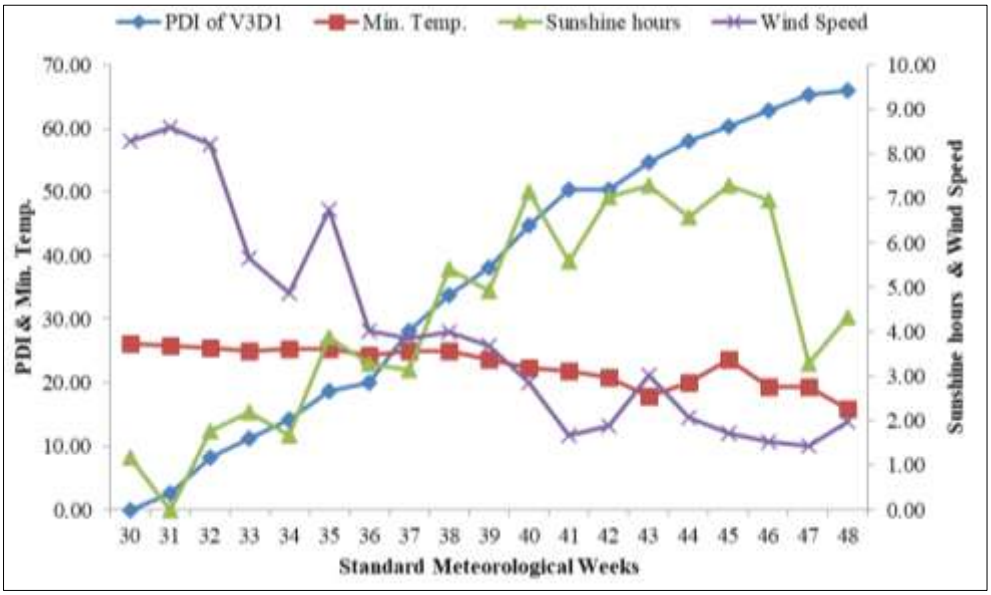


Fig 3: Stepwise regression model for moderately resistant variety/ genotype (V2) of desi cotton and sowing dates (D1, D2 & D3) against root rot disease incidence and weather parameters (Pooled: 2018-19 & 2019-20)



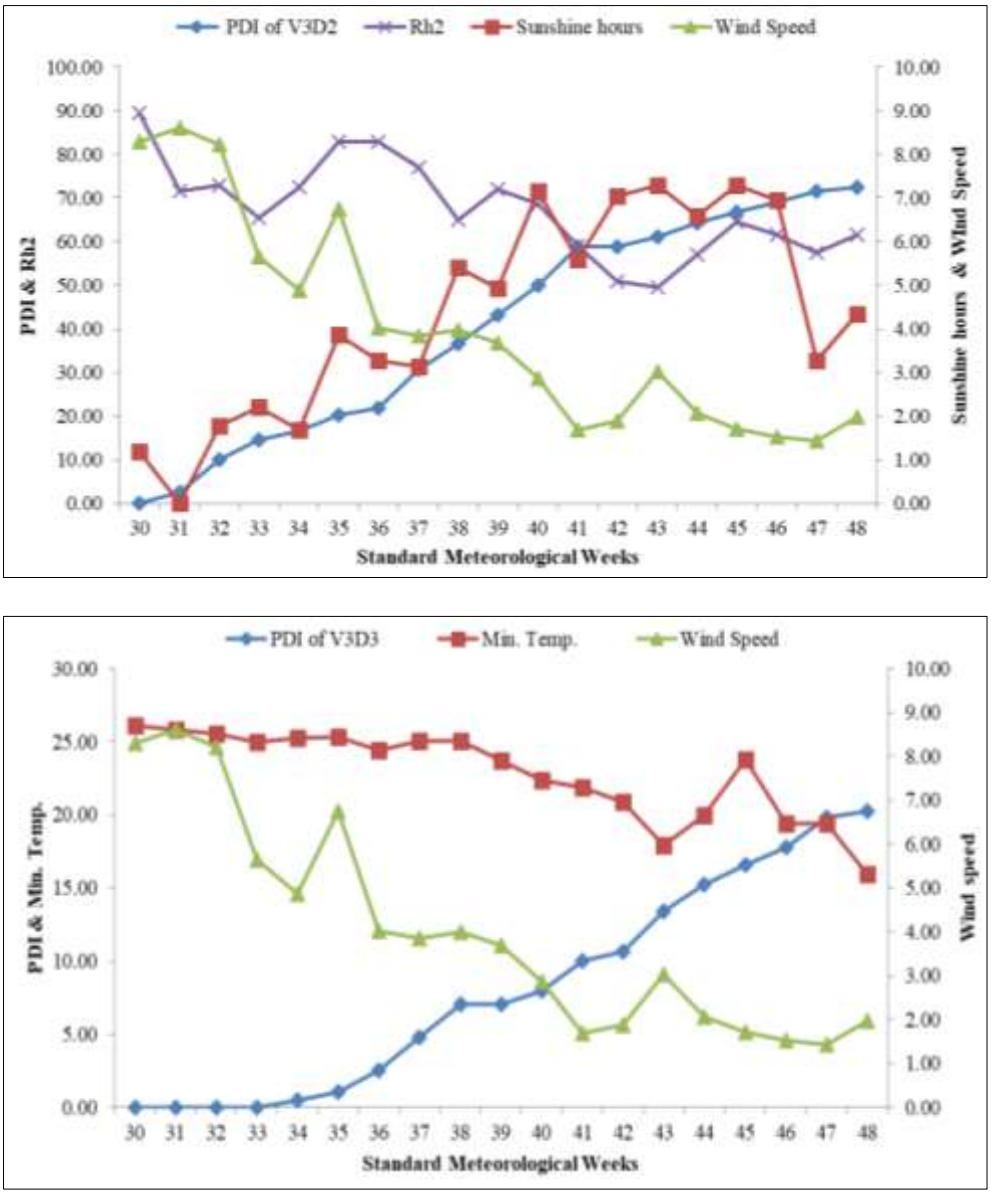


Fig 4: Stepwise regression model for susceptible variety/ genotype (V3) of desi cotton and sowing dates (D1, D2 & D3) against root rot disease incidence and weather parameters (Pooled: 2018-19 & 2019-20)

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