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RESEARCH ARTICLE

Influence of weather parameters on tikka (*Cercospora* spp.) and rust (*Puccinia arachidis*) of groundnut (*Arachis hypogaea* L.)

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ABSTRACT : The experiment was laid out in Randomized Block Design with five sowing dates *viz.*, S_1 -22nd June, S_2 -29th June, S_3 -6th July, S_4 -13th July and S_5 -20th July and four replications. The data revealed that in case of tikka disease there was positive significant correlation between disease intensity and maximum temperature (0.66), morning relative humidity (0.34), evaporation (0.39) and bright sunshine hours (0.65), whereas, minimum temperature (-0.55), evening relative humidity (-0.69), wind speed (-0.73) and rainy days (-0.26) showed negatively significant correlation with disease intensity in *Kharif* season and wind speed, rain and rainy days are responsible for development tikka disease intensity. In rust disease maximum temperature (0.59), morning relative humidity (0.33), evaporation (0.33) and bright sunshine hours (0.55) showed positive correlation with disease intensity. Whereas, minimum temperature (-0.44), evening relative humidity (-0.58) and wind speed (-0.63), showed negatively significant correlation with disease intensity in *Kharif* season. Other climatic factors *i.e.*, rainfall showed no significant correlation with disease intensity. The morning relative humidity and bright sunshine hours were correlated for rust disease incidence. From the multiple regression it is seen that the tikka disease severity was significantly related with wind speed (-5.53), rain (0.12) and rainy days (-4.46) and these factors were found to be significantly superior among the all weather parameters. The multiple regression equation developed is: $Y= 66.750-5.536WS^{(W-1)} + 0.124RAIN^{(W-1)} -4.463\ RAINY\ DAYS^{(W-1)}$. The result from all the relevant observations indicated that the morning relative humidity (2.87) and bright sunshine hours (5.65) during the crop growing period was found to be highly significant weather conditions for rust disease development among the all other weather parameters. The multiple regression equation developed is as: $Y= -257.591 +2.879RH\text{-}I^{(W-1)} +5.651BSS^{(W-1)}$.

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Groundnut (*Arachis hypogaea* L.)is subjected to various fungal, bacterial and viral diseases which are air borne or soil borne. The rust of groundnut caused by *Puccinia arachidis* Speg. was reported from Punjab in 1969 (Chahal and Chohan, 1969) and now it is common in occurrence in most groundnut growing states in India (Mayee *et al.*, 1977 and Subrahmanyam *et al.*, 1979). *Uredospores* are the main source of inoculums of rust disease of groundnut of which the dispersal is brought about on large scale. Among the diseases, *Cercospora* leaf spot and rust cause heavy economic yield losses. For occurrence of these diseases on groundnut crop the weather plays an important role. The temperature, rainfall, relative humidity, prolonged cloudy weather are the major weather parameters for occurrence and growth of tikka and rust disease incidence in groundnut crop. Therefore, the present investigation is undertaken to study the influence of weather parameters on tikka and rust of groundnut.

EXPERIMENTAL METHODOLOGY

The experiment was laid out in Randomized Block Design with five treatments: five sowing dates *viz*., S_1-22nd June, S_2-29th June, S_3-6th July, S_4-13th July and S_5-20th July and four replications. The soil of the experimental plot was medium deep with good drainage and was suitable for growth of the groundnut crop. The daily observations on weather parameters *viz*., rainfall, humidity (RH-I and RH-II), rainy days, evaporation, bright sunshine hours and wind speed were regularly recorded during the period of experiment.

Incidence pattern of tikka (*Cercospora* spp.) and rust (*P. arachidis*) disease :

The incidence pattern of the tikka and rust diseases, number of infected plants at seven days interval from 30 days after sowing were recorded and percentage of infected plants was worked out. Per cent disease incidence was calculated using following formula :

$$\text{PDI} = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}}$$

Disease intensity is calculated by following formula :

$$\text{Disease intensity (\%)} = \frac{0(X_0) + 1(X_1) + 2(X_2) + \ldots \times 100}{X_0 + X_1 + X_2 + \ldots \times \text{Max. grade used}}$$

where, X represents the number of diseased entities within a sampling unit in the respective class or grade such as 0, 1, 2, …. 9

The effect of climatic factors *viz*., temperature, humidity, rainfall and bright sun shine hours on tikka and rust disease intensity due to various sowing dates were also studied. The correlation and regression equations are also worked out by the following formulae between different sowing dates and per cent disease intensity.

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots + b_nx_n.$$

where, Y= PDI, 'a' as constant and 'b' as regression co-efficients of independent variable 'x'.

Effect of weather on occurrence of tikka and rust disease of groundnut :

The multiple regression analysis was also worked out between tikka and rust disease intensity and climatic factors for one week prior study showing significant correlations between dependent and independent factors. The influence of factors on tikka and rust disease incidence was estimated by using prediction equation as,

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots\ldots + b_nx_n$$

where, Y= PDI, 'a' as constant and 'b' as regression co-efficients of independent variable 'x'.

Effect of biometeorological factors on disease intensity in *Kharif* seasons :

The influence of factors on tikka and rust disease intensity was estimated by using prediction equation as,

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots\ldots + b_nx_n$$

where, Y= PDI, 'a' as constant and 'b' as regression co-efficients of independent variable 'x'.

Diseases severity :

The scale explained by Mayee and Datar (1986) was used to record field observations on tikka and rust diseases of groundnut.

Statistical analysis and interpretation of data :

The tabulated data were statistically processed by the standard method of analysis of variance for the Randomized Block Design and test of significance as given by Panse and Sukhatme (1985).

Backward elimination (step down) :

The backward elimination procedure is basically a sequence of tests for significance of explanatory variables. Starting out with the maximum model, the variable was eliminated with the highest p-value for the test of significance of the variable, conditioned on the p-value being bigger than some pre-determined level (say, 0.05).

EXPERIMENTAL FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Wet pod weight kg plot^{-1} and q ha^{-1} :

The observations on wet pod weight kg plot^{-1} and q

ha^{-1} as influenced by different dates of sowing are recorded and presented in Table 1. Among the various sowing date treatments, the wet pod weight $plot^{-1}$ were differed statistically and differences were found to be significant. The statistically highest wet pod weight was observed under S_3 during 6th July sowing date (4.23 kg $plot^{-1}$) and (36.83 q ha^{-1}) than rest of the treatments.

However, the next best treatment was S_1 that is sowing the crop during 22nd June was registered significant highest pod yield and it was found to be at par with the treatment S_2 that is sown during 29th June and treatment S_4 (13th July) for pod yield kg $plot^{-1}$.This was closely followed by treatment S_2 that is sowing during 29th June was found to be significant in both kg $plot^{-1}$ and q ha^{-1} and it was found to be at par with the treatment S_4 in kg $plot^{-1}$. The maximum yield in this treatment was might be due to maximum use of light and significantly well distributed rainfall and climatic conditions during crop growing period. Whereas, treatment S_5 (20th July) recorded significantly lowest pod yield of groundnut. Thus, it can be concluded that the treatment sowing date (S_3) 6th July green pod weight was significantly superior over all other remaining treatments.

Similar results were reported by Shantimalliah *et al.* (1979) showed that pod yield of groundnut from early sowings was higher, and that groundnut could be sown up to the first fortnight of July without much reduction in yield.

The data pertaining to dry pod weight kg $plot^{-1}$ and q ha^{-1} as influenced by different dates of sowing are recorded and presented in Table 1.

The differences in pod yield in kg $plot^{-1}$ and q ha^{-1} were found significant due to different sowing date treatments under study. The significantly higher values of dry pod yield in kg $plot^{-1}$ and q ha^{-1} was registered with sowing date (S_3) during 6th July than rest of the treatments. However, it was followed by treatment S_1 which registered highest pod yield and it was at par with treatment S_2 that is sowing during 29th June in dry pod weight kg $plot^{-1}$. Whereas, treatment S_5 (20th July) recorded statistically lowest pod yield of groundnut (1.65 kg $plot^{-1}$ and 16.11 q ha^{-1}). Thus, it can be concluded that the treatment sowing date (S_3) 6th July was found significantly superior over all other remaining treatments in producing dry pod weight Similar results were reported by Lewin *et al.* (1979). He concluded that the crop sown on second fortnight of June gave the highest yield followed by the crop sown on July 7th.

Disease observations (Symptomatology) :

The symptomatology of tikka and rust diseases of groundnut was studied under field conditions during *Kharif* season. Symptomatology was studied by recording observations on growing plants sown on five different dates in *Kharif* season. The first symptom of tikka and rust disease normally appeared on groundnut in *Kharif* and it was observed 25-30 days after sowing in all sowing dates. The sequence of development of symptoms in all sowing dates was similar however, differed in conspicuousness and the severity.

Tikka (*Cercospora arachidicola* and *Cercospora personata*) :

The first symptom of tikka disease (plate number-2) was lesions normally developed on the older leaves near ground level. The conidia produced on them are disseminated by wind, rain splash and insects leading to secondary infections, within 10-15 days. The conidia are a source of inoculums was observed by Karunakaran and Raj (1973). The small chlorotic spots appeared on leaflets which developed in about five days into mature, sporulating lesions. Lesions caused by *Cercospora arachidicola* were sub circular and 1 to over 10 mm in diameter. They were dark brown on the adaxial (upper)

Table 1 : Number of wet pod weight $plot^{-1}$ in kg and ha^{-1} and dry pod weight $plot^{-1}$ in kg and ha^{-1} of groundnut by different sowing dates

Sr. No.	Sowing dates	Wet pod weight $plot^{-1}$ (kg)	Wet pod weight ha^{-1}(q)	Dry pod weight $plot^{-1}$ (kg)	Dry pod weight ha^{-1} (q)
1.	S_1 (22nd June)	3.38	31.96	2.41	24.56
2.	S_2 (29th June)	3.20	25.94	2.20	20.54
3.	S_3 (6th July)	4.23	36.83	3.15	32.83
4.	S_4 (13th July)	3.05	23.83	2.18	19.06
5.	S_5 (20th July)	2.33	21.86	1.65	16.11
	S.E. ±	0.21	0.61	0.11	0.65
	CD (P=0.05)	0.65	1.90	0.34	2.01
	General mean	3.24	28.08	2.32	22.62

surface of the leaflet, where most sporulation occured, and of a lighter shade of brown on the abaxial (lower) surface. Lesions formed by *Cercospora personata* were smaller, nearly circular and darker than those formed by *Cercospora arachidicola* on the abaxial surface, the lesions were black and slightly rough in appearance. In *Cercospora arachidicola* a chlorotic halo was present around the lesions.

In addition to causing leaf spots, they produced lesions on petiols, stems and pegs. The lesions were oval to elongate and had more distinct margins than the leaflet lesions. When the disease attack was severe, the affected leaflet became chlorotic, then necrotic, the lesions coalesced and finally resulted in shedding of leaflets. While working with leaf spot disease of groundnut similar results were reported by Kucharek (1975). The conidia is a source of inoculums was observed by Karunakaran and Raj (1973).The overall similar disease symptoms were observed by Woodroof (1933); Porter *et al.* (1982); Subramanyam and Mc Donald (1970).

Rust (*Puccinia arachidis*) :

In case of rust disease the sequence of development of symptoms in all different sowing dates was similar however, differed in conspicuouness and the severity. The first symptom of disease was appearance of the orange coloured pustules or uredinia on the abaxial (lower) surface of the leaves and ruptured to expose masses of reddish-brown urediniospores (uredospores). They formed on all aerial plant parts apart from flowers and pegs. In contrast with rapid defoliation associated with leaf spots, rust affected leaves became necrotic but tend to remain attached to the plants.

While, working with groundnut rust disease the similar results were observed by Subrahmanyam and Mc Donald (1982). They concluded that, it is greatly influenced by environmental factors and also similar results were observed by Mallaiah (1976) and Sokhi and Jhooty (1982). The wind born urediniospores land on the leaf surface and with temperature in the 15 to 30°C range and in presence of water film, germinate and produce appressoria and infection hyphae, penetrating the leaf through the stomata. The incubation period ranges from 9 to 20 days; being greatly influenced by environmental factors and host. Pustules appeared first on the abaxial surface, and in highly susceptible plants the original pustules surrounded by the colonies of secondary pustules. They later form on the adaxial surface opposite to those on the abaxial surface and were usually circular and ranging from 0.5 to 1.4 mm in diameter.

Per cent disease intensity of tikka and rust of groundnut in sowing dates :

The data on tikka and rust disease intensity of five sowing dates are depicted in Table 2. The data indicated that the occurrence of the tikka and rust of groundnut was observed throughout the *Kharif* season, normally 30 days after sowing and then up to the harvesting. The disease intensity was higher mostly in the month of September. Among all sowing dates studied, the average tikka and rust intensity level were higher in second date of sowing that is 80.15 per cent tikka and 95.56 per cent rust in *Kharif* season, respectively. The first incidence of tikka disease was observed 30 DAS in S_1, S_2, S_3, S_4 treatments and 56 DAS in S_5. In case of rust it was observed 30 DAS in S_1, S_2 and 45 DAS in S_3, S_4 and S_5

Table 2 : Development of tikka and rust disease in different sowing dates during *Kharif* season

Sr. No.	Sowing dates	Tikka disease intensity (%) days after sowing												
		30	37	42	49	56	63	70	77	82	89	96	105	At harvest
1.	S_1 (22ndJune)	0.19	1.89	9.50	12.14	20.46	28.95	46.19	48.67	56.75	59.05	60.37	61.79	67.04
2.	S_2 (29th June)	1.63	4.19	6.30	22.96	43.33	47.78	54.22	57.48	66.89	70.74	73.55	77.75	80.15
3.	S_3 (6th July)	0.26	0.52	6.86	11.48	16.38	18.22	21.53	29.14	33.48	40.30	41.56	56.17	53.99
4.	S_4 (13th July	0.33	1.20	3.56	6.96	7.20	12.04	13.89	34.96	42.52	48.74	49.22	58.44	62.22
5.	S_5 (20th July)	0	0	0	0	1.52	6.72	10.23	25.74	30.48	41.63	47.23	51.48	56.49
Rust disease intensity (%) days after sowing														
1.	S_1 (22ndJune)	0.87	3.45	6.34	19.37	22.69	30.22	34.86	38.96	45.52	64.48	66.38	75.45	85.46
2.	S_2 (29th June)	1.19	3.33	8.11	9.12	14.59	19.38	28.34	45.96	65.45	76.13	89.12	91.42	95.56
3.	S_3 (6th July)	0	0.20	0.40	0.93	1.59	1.63	1.67	3.90	4.68	7.91	10.39	19.78	22.42
4.	S_4 (13th July	0	0	0.54	1.23	3.06	3.66	8.42	15.6	33.54	42.12	49.69	52.99	55.25
5.	S_5 (20th July)	0	0	0	0.52	0.93	3.57	3.95	8.64	10.52	19.32	20.96	22.46	24.79

treatments. The outbreak was not uniform for both the diseases, the maximum intensity in all the five dates of sowing in *Kharif* season was observed between 65 to 79 days after sowing.

Tikka (*Cercospora* spp.) :

The data on disease intensity depicted in Table 2 indicated that in *Kharif* season the tikka disease incidence exponentially increased during 30 MW to 41 MW from 28.95 per cent to 67.04 per cent, during 33 MW to 42 MW from 6.3 per cent to 80.15 per cent, during 29 MW to 42 MW from 6.86 per cent to 56.99 per cent, during 35 MW to 44 MW from 6.96 per cent to 62.22 per cent, 38 MW to 44 MW from 6.72 per cent to 56.49 per cent in S_1, S_2, S_3, S_4 and S_5 treatments, respectively.

From the observed disease intensity it is concluded that the tikka disease incidence was initiated after 30 of sowing and thereby increased up to the harvest. Relative humidity, rain and rainy days and other climatic conditions during crop growing period were found to be significantly correlated with disease development. The similar disease severity progress was observed by Gupta and Saharan (1974) and they concluded that the *Cercospora* leaf spot on *urdbean* was severe in early sown crop. Also Rewal and Bedi (1976) studied that the late sown mungbean crop developed much less disease compared to the early sown mundbean crop. Awurum (2000) reported that planting date had significant effect on the incidence and severity of these diseases.

Rust (*Puccinia arachidis*) :

The data on rust disease intensity depicted in Table 2 indicated that in *Kharif* season the rust disease intensity exponentially increased during 31 MW to 41 MW from 6.34 per cent to 85.46 per cent, during 32 MW to 42 MW from 8.11 per cent to 95.56 per cent, during 38 MW to 43 MW from 3.9 per cent to 22.42 per cent, during 37 MW to 44 MW from 3.66 per cent to 55.25 per cent, from 39 MW to 45 MW from 3.95 per cent to 24.79 per cent in S_1, S_2, S_3, S_4 and S_5 sowing date treatments, respectively.

It is revealed that the favourable climatic conditions for disease development were temperature ranged between 26°C to 32°C and relative humidity ranged between 61-79 per cent. It was evident from the Table 2 that the disease intensity increased with variation in climatic conditions. Normally disease appearance was started from 30 DAS and thereby increased up to the harvesting time. The similar results were observed by following scientist in groundnut crop, they revealed that the rust disease was mainly associated with actual date of sowing and varying climatic conditions. Kolte (1986) and Gupta *et al*. (1990) observed reported that the severity of white rust development was found to be highly significant among the dates of sowing.

Effect of biometeorological factors on disease intensity and pathogenesis of tikka of groundnut :

The effect of bio-meteorological factors *viz.*, PDI, maximum and minimum temperatures, morning and evening humidity, rainfall, rainy days, evaporation, wind speed and bright sunshine hours on PDI of tikka of groundnut was studied in same week (0-week), one week prior (W^{-1}) and two weeks prior (W^{-2}). The data on PDI on each plant considered from the earlier observations for calculating the correlation co-efficients. The correlation co-efficients worked out for PDI and different climatic factors are depicted in Table 3.

Among studied factors in *Kharif* season on tikka disease the multiple regression analysis by step down method was worked out wherein PDI of W^0 taken as a dependent variables and W^{-1} (one week prior) PDI, W^{-2} (two weeks prior) PDI as well as weather parameters of (W°), (W^{-1}), (W^{-2}) weeks as a independent variables. Multiple regression analysis was carried out and regression equation worked out and depicted in Table 4.

In case of tikka disease for first date of sowing (W^{-1}) PDI for one week prior, (W^{-2}) PDI of two weeks prior (0.97), maximum temperature (0.63) and bright sunshine hours (0.67) of same week were found to be significant and positively correlated with PDI. Minimum temperature (-0.76), evening relative humidity (-0.70) and wind speed (-0.77) were found to be significant and negatively correlated as well as for one week prior weather parameters, maximum temperature (0.62) and bright sunshine hours (0.65) found to be significant and positively correlated with PDI. Evening relative humidity (-0.69) and wind speed (-0.77) were found to be significant and negatively correlated. In two weeks prior weather parameters morning relative humidity (0.59) was found to be significant and positively correlated with PDI. Further wind speed (-0.69) is significant but negatively correlated.

In second date of sowing (W^{-1}: one week prior PDI

Table 3: Correlation co-efficient between bio meteorological factors and tikka and rust disease intensity in groundnut in five different sowing dates

Sr. No.	Particulars	'r' values for groundnut diseases									
		Tikka					Rust				
	Climatic factors	S_1 (22nd June)	S_2 (29th June)	S_3 (6th July)	S_4 (13th July)	S_5 (20th July)	S_1 (22nd June)	S_2 (29th June)	S_3 (6th July)	S_4 (13th July)	S_5 (20th July)
1.	Temp. (max.) °c	0.639*	0.703**	0.785**	0.877**	0.891**	0.788**	0.861**	0.775**	0.897**	0.872**
2.	Temp. (min.) °c	-0.761**	-0.653**	-0.784**	-0.841**	-0.879**	-0.836**	-0.778**	-0.905**	-0.827**	-0.881**
3.	Rh I am (%)	-0.464	0.419	0.283	0.295	0.243	0.474	0.460	0.279	0.315	0.238
4.	Rh II pm (%)	-0.704**	-0.728**	-0.838**	-0.914**	-0.947**	-0.833**	-0.885**	-0.906**	-0.921**	-0.945**
5.	Wind speed (km/hr)	-0.775**	-0.819**	-0.909**	-0.940**	-0.923**	-0.846**	-0.900**	-0.848**	-0.948**	-0.912**
6.	Rainfall (mm)	0.128	0.030	-0.069	-0.110	-0.205	0.125	0.018	-0.021	-0.097	-0.197
7.	Rainy days	-0.098	-0.217	-0.299	-0.319	-0.370	-0.155	-0.223	-0.141	-0.310	-0.376
8.	Evaporation (mm/day)	0.278	0.406	0.450	0.571*	0.541*	0.339	0.419	0.380	0.565*	0.518*
9.	Bright sunshine hours/day	0.674**	0.736**	0.798**	0.851**	0.835**	0.756**	0.822**	0.786**	0.853**	0.836**

* and ** indicate significance of values at P=0.05 and P=0.01, respectively

Table 3(a) : Correlation co-efficient between bio meteorological factors and tikka and rust disease intensity in groundnut in five different sowing dates

Sr. No.	Particulars	'r' values for groundnut diseases									
		Tikka					Rust				
	Climatic factors	S_1 (22nd June)	S_2 (29th June)	S_3 (6th July)	S_4 (13th July)	S_5 (20th July)	S_1 (22nd June)	S_2 (29th June)	S_3 (6th July)	S_4 (13th July)	S_5 (20th July)
1.	Temp. (Max.) °C	0.621*	0.651**	0.796**	0.859**.	0.904**	0.732**	0.811**	0.860**	0.872**	0.883**
2.	Temp. (Min.) °C	-0.532	-0.593*	-0.695**	-0.788**	-0.827**	-0.666**	-0.786**	-0.827**	-0.777**	-0.824**
3.	RH I am (%)	0.385	0.450	0.478	0.316	0.294	0.419	0.521*	0.447	0.326	0.344
4.	RHII pm (%)	-0.697**	-0.719**	-0.836**	-0.912**	-0.938**	-0.807**	-0.880**	-0.900**	-0.905**	-0.920**
5.	Wind speed (km/hr)	-0.779**	-0.795**	-0.872**	-0.922**	-0.912**	-0.851**	-0.883**	-0.893**	-0.914**	-0.921**
6.	Rainfall (mm)	0.135	0.099	0.038	0.67	-0.39	0.115	0.190	0.022	-0.037	0.004
7.	Rainy days	-0.242	-0.304	-0.347	-0.377	-0.313	-0.212	-0.166	-0.190	-0.352	-0.275
8.	Evaporation (mm/day)	0.432	0.360	0.432	0.539*	0.529*	0.474	0.408	0.392	0.542*	0.485*
9.	Bright sunshine hours/day	0.653*	0.695**	0.796**	0.861**	0.852**	0.740**	0.792**	0.764**	0.856**	0.819**
10.	Disease intensity (%)	0.988**	0.985**	0.983**	0.986**	0.985**	0.988**	0.993**	0.980**	0.988**	0.981**

* and ** indicates significance of values at P=0.01 and P=0.05, respectively

Table 3(b) : Correlation co-efficient between bio meteorological factors and tikka and rust disease intensity in groundnut in five different sowing dates

Sr. No.	Particulars	'r' values for groundnut diseases									
		Tikka					Rust				
	Climatic factors	S_1 (22nd June)	S_2 (29th June)	S_3 (6th July)	S_4 (13th July)	S_5 (20th July)	S_1 (22nd June)	S_2 (29th June)	S_3 (6th July)	S_4 (13th July)	S_5 (20th July)
1.	Temp. (Max.) ^{0}C	0.292	0.454	0.625**	0.765**	0.819**	0.462	0.638*	0.809**	0.759**	0.819**
2.	Temp. (Min.) ^{0}C	-0.411	-0.492	-0.656**	-0.715**	-0.779**	-0.565*	-0.728**	-0.746**	-0.711**	-0.756**
3.	RH I am (%)	0.592*	0.584*	0.566*	0.490*	0.427*	0.503	0.494	0.746**	0.462*	-0.442*
4.	RHII pm (%)	-0.437	-0.528*	-0.715**	-0.826**	-0.876**	-0.616*	-0.721**	-0.836**	-0.818**	-0.865**
5.	Wind speed (km/hr)	-0.693**	-0.663**	-0.822**	-0.879**	-0.900**	-0.727**	-0.809**	-0.916**	-0.872**	-0.914**
6.	Rainfall (mm)	0.041	0.141	0.167	0.074	0.131	0.015	0.243	0.478	0.093	0.137
7.	Rainy days	-0.345	-0.296	-0.244	-0.331	-0.221	-0.354	-0.182	0.048	-0.293	-0.220
8.	Evaporation (mm/day)	0.257	0.294	0.245	0.416*	0.383	0.390	0.419	0.229	0.419	0.378
9.	Bright sunshine hours/day	0.507	0.576*	0.672**	0.803**	0.804**	0.660*	0.709**	0.666**	0.802**	0.788**
10.	Disease intensity (%)	0.973**	0.961**	0.975**	0.971**	0.957**	0.985**	0.983**	0.978**	0.962**	0.965**

* and ** indicates significance of values at P=0.01 and P=0.05, respectively

(0.98), (W^{-2}: two week prior PDI (0.96), maximum temperature (0.70) and bright sun shine hours (0.73) of same week were found to be highly significant and positively correlated. minimum temperature (-0.65), evening relative humidity (-0.72) and wind speed (-0.81) were found to be significant and negatively correlated. As well as maximum temperature (0.65) and bright sun shine hours (0.69) of (W^{-1}) one week prior and morning relative humidity (0.59) and bright sunshine hours (0.57) of W^{-2} weeks were found to be significant and positively correlated and minimum temperature (-0.59), evening relative humidity (-0.71) and wind speed (-0.79) of W^{-1} week and evening relative humidity (-0.43) and wind speed (-0.69) of W^{-2} weeks were found to be significant negatively correlated.

In third date of sowing (W^{-1}: one week prior PDI (0.98), (W^{-2}: two week prior PDI (0.97), maximum temperature (0.78) and bright sunshine hours (0.79) of W^{0} week, maximum temperature (0.79) of one week prior W^{-1} and minimum temperature (-0.65), morning relative humidity (0.56) and bright sun shine hours (0.67) of W^{-2} weeks were found to be significant and positively correlated. As well as and minimum temperature (-0.78), evening relative humidity (-0.83) and wind speed (-0.90) of (W^{0}) same week, minimum temperature (-0.69), evening relative humidity (-0.83) and wind speed (-0.87) of (W^{-1}) preceding week and minimum temperature (-0.65), evening relative humidity (-0.71) and wind speed (-0.82) and rainy day (-0.24) of (W^{-2}) two weeks prior were found to be highly significant and negatively correlated.

In last two dates of sowing (W^{-1}: one week prior PDI (0.98), (W^{-2}: two week prior PDI (0.97), maximum temperature (0.87), evaporation (0.57) and bright sun shine hours (0.85) of (W^{0}) same week, (W^{-1}) a previous week, maximum temperature (0.76), morning relative humidity (0.49) and bright sun shine hours (0.80) of (W^{-2}) two weeks prior, were found to be highly significant and positively correlated. As well as minimum temperature, evening relative humidity and wind speed of (W^{0}), (W^{-1}), (W^{-2}) week were found to be highly significant and negatively correlated.

From all the observations and results it is concluded that, for development of tikka disease in 22nd June sowing the bio-meteorological parameters that is PDI of one week prior and rain and rainy days were found to be significantly superior and highly correlated among the all other parameters.

For 29th June sowing the bio-meteorological parameters that is PDI of one week prior and maximum temperature, morning relative humidity, evening relative humidity, rainy days and evaporation rate of same week as well as maximum temperature of one week prior were found to be significantly superior and highly correlated among the all other parameters. For 6th August sowing the bio-meteorological parameters that is PDI of one week prior and maximum temperature, minimum temperatures, wind speed and rainy days of same week were found to be significantly superior and highly correlated among the all other parameters. For 13th August sowing the bio-meteorological parameters that is PDI of one week prior bright sun shine hours and rainy days of same week ware found to be significantly superior and highly correlated among the all other parameters.

For delayed sowing 20th August the bio-meteorological parameters that are PDI of one week prior and wind speed of same week were found to be significantly superior and highly correlated among the all other parameters.

Singh *et al.* (1990) and Singh (1984) studied that the tikka leaf spot intensity was positively correlated with maximum temperature (0.48), minimum temperature (0.42), evaporation (0.61) and age (0.51) of the crop.

Effect of biometerological factors on disease intensity and pathogenesis of rust of groundnut :

The effect of bio-meteorological factors *viz.*, PDI, maximum and minimum temperatures, morning and evening humidity, rainfall, rainy days, evaporation rate wind speed and bright sunshine hours on PDI groundnut was studied in same week (0-week), one week prior (W^{-1}) and two weeks prior (W^{-2}). The data on PDI on each plant considered from the earlier observations for calculating the correlation co-efficients. The correlation co-efficients worked out for PDI and different climatic factors are depicted in Table 3.

Among studied factors in *Kharif* season on rust the multiple regression analysis by step down method was worked out and PDI of W^{0} taken as a dependent variable and W^{-1} (one week prior) PDI, W^{-2} (two weeks prior) PDI as well as weather parameters of (W^{0}), (W^{-1}), (W^{-2}) weeks as a independent variables. Multiple regression analysis was carried out and regression equation worked out is as follows.

In case of rust disease in first date of sowing (W^{-1}: PDI of one week prior (0.98), (W^{-2}: two week prior PDI (0.98) and maximum temperature (0.78) and bright sun shine hours (0.75, 0.74) of (W^{0}) week, (W^{-1}) week and bright sunshine hours (0.66) of (W^{-2}) weeks were found to be highly significant and positively correlated. The minimum temperature (-0.83, -0.66, -0.56), evening relative humidity (-0.83, -0.80, -0.61) and wind speed (-0.72) of (W^{0}), (W^{-1}), (W^{-2}) week were found to be highly significant but negatively correlated.

In second and third date of sowing (W^{-1}: one week prior PDI (0.98,0.99), (W^{-2}: two week prior PDI (0.98, 0.97) and maximum temperature (0.86, 0.81, 0.63) and bright sunshine hours (0.82, 0.79, 0.70) of (W°), (W^{-1}), (W^{-2}) weeks were found to be highly significant and positively correlated. As well as minimum temperature (-0.77, -0.78, -0.72), evening relative humidity (-0.88, -0.88, -0.61) and wind speed (-0.90, -0.88, -0.80) of (W^{0}), (W^{-1}), (W^{-2}) week were found to be highly significant but negatively correlated.

In last two dates of sowing (W^{-1}: one week prior PDI (0.98), (W^{-2}: two week prior PDI (0.96) and maximum temperature (0.89, 0.87, 0.75), evaporation (0.56, 0.54, 0.41) and bright sun shine hours (0.85, 0.85, 0.80) of (W°), (W^{-1}), (W^{-2}) weeks were found to be highly significant and positively correlated. As well as minimum temperature (-0.82, -0.77, -0.71), evening relative humidity (-0.92, -0.90, -0.81) and wind speed (-0.94, -0.91,-0.87) of (W°), (W^{-1}), (W^{-2}) week were found to be highly significant but negatively correlated.

From Table 4 and 5 it is concluded here that, for development of rust disease in 22nd June sowing the bio-meteorological parameters that is PDI of one week prior, bright sun shine hours of same week and two week prior were found to be significantly superior and highly correlated among the all other parameters.

For 29th June sowing the bio-meteorological parameters that is PDI of one week prior, maximum temperature and wind speed of same week and maximum temperature and morning relative humidity of two week prior ware found to be significantly superior and highly correlated among the all other parameters. For 6th August sowing the bio-meteorological parameters that is PDI of one week prior and maximum temperature of one week prior ware found to be significantly superior and highly correlated among the all other parameters. For 13th August sowing the bio-meteorological parameters that is PDI of one week prior, bright sunshine hours and morning relative humidity of same week and minimum temperature of two weeks prior were found to be significantly superior and highly correlated among the all other parameters. For 20th August sowing the bio-meteorological parameters that is PDI of one week prior, evening relative humidity, rain and wind speed of same week ware found to be significantly superior and highly correlated among the all other parameters. Similar results

Table 4 : Regression equations for groundnut tikka disease development over different sowing dates

Sr. No.	Sowing dates	Equations	R^2
1.	S_1 (22nd June)	$PDI=-3.854+0.982PDI^{(W-1)}-0.058RAIN^{(W0)}+1.750RD^{(W0)}$	0.981
2.	S_2 (29th June)	$PDI=-247.977+0.967PDI^{(W-1)}-1.794T(MAX)^{(W0)}+5.284RH\text{-}I^{(W0)}+1.091RH\text{-}II^{(W0)}-3.896RD^{(W0)}+2.250EVA^{(W0)}+5.806T(MAX)^{(W-1)}$	0.998
3.	S_3 (6th July)	$PDI=44.919+0.901PDI^{(W-1)}-1.755T(MAX)^{(W0)}+1.435T(MIN)^{(W0)}-2.641WS^{(W0)}-1.628RAIN^{(W0)}$	0.990
4.	S_4 (13th July	$PDI=-5.829+0.823PDI^{(W-1)}+2.207BSS^{(W0)}+1.178RD^{(W0)}$	0.987
5.	S_5 (20th July)	$PDI=13.947+0.849PDI^{(W-1)}-1.653WS^{(W0)}$	0.980

Table 5 : Regression equations with for groundnut rust disease development over different sowing dates

Sr. No.	Sowing dates	Equations	R^2
1.	S_1 (22nd June)	$PDI=11.148+1.229PDI^{(W-1)}-1.761BSS^{(W-2)}-1.718BSS^{(W0)}$	0.988
2.	S_2 (29th June)	$PDI=113.538+0.971PDI^{(W-1)}-3.635T(MAX)^{(W-2)}+2.444WS^{(W0)}-0.360RH\text{-}I^{(W-2)}+0.481T(MAX)^{(WO)}$	0.998
3.	S_3 (6th July)	$PDI=-27.284+0.931PDI^{(W-1)}+1.032T(MAX)^{(W-1)}$	0.981
4.	S_4 (13th July	$PDI=-88.237+0.712PDI^{(W-1)}+2.619BSS^{(W0)}+1.016RH\text{-}I^{(W0)}-.294T(MIN)^{(W-2)}$	0.992
5.	S_5 (20th July)	$PDI=28.903+0.503PDI^{(W-1)}-0.216RH\text{-}II^{(W0)}-1.556WS^{(W0)}-0.007RAIN^{(W0)}$	0.978

was reported by Singh *et al*. (1990) Mayee (1986) and Mayee and Kokate (1987).

Effect of climatic factors on tikka disease intensity:

The data on correlation co-efficient between disease intensity and various climatic factors is detailed in Table 6. The data revealed that in case of tikka disease there was positive significant correlation between disease intensity and maximum temperature (0.66), morning relative humidity (0.34), evaporation rate (0.39) and bright sun shine hours (0.65), whereas, minimum temperature (-0.55), evening relative humidity (-0.69) and wind speed (-0.73), and rainy days (-0.26) showed negatively significant correlation with disease development in *Kharif* season.

The overall step down multiple regression analysis was worked out between PDI of (W^0) same week with weather parameters of one week prior (W^{-1}) for all sowing dates. The results obtained are given as follows.

The multiple regression equation is given below :

Y= 66.750 -5.536WS$^{(W-1)}$ + 0.124RAIN$^{(W-1)}$ -4.463RAINY DAYS$^{(W-1)}$

From the overall step-down regression analysis here it is concluded that the tikka disease severity was significantly related with wind speed (-5.53), rain (0.12) and rainy days (-4.43). These variables showed favourable condition for disease progress in *Kharif* season. Similar results were reported by Pandu and Apparao (1979). Verma and Patel (1969) reviewed that *Cercospora cruenta* on cowpea

Effect of climatic factors on rust disease intensity :

The data on correlation co-efficient between disease intensity and various climatic factors is given in Table 6. In case of the rust disease maximum temperature (0.59), morning relative humidity (0.33), evaporation (0.33) and bright sun shine hours (0.55) showed positive correlation with disease development. Whereas, minimum temperature (-0.44), evening relative humidity (-0.58), wind speed (-0.63), showed negatively significant correlation with disease progress in *Kharif* season. Other climatic factors *Kharif* rainfall and rainy days showed no significant correlation with rust disease. The overall step down multiple regression analysis was worked out between PDI of W0 week with weather parameters of one week prior for all sowing dates. The results obtained are given as follows. The multiple regression equation is given below :

Y= -257.591 +2.879RH-I$^{(W-1)}$ +5.651BSS$^{(W-1)}$

The result from experimentation indicated that the morning relative humidity (2.87) and bright sun shine hours (5.65) during the crop growing period was found to be highly significantly superior weather conditions for rust disease development among the all other weather parameters. The similar results were quoted by Mayee (1986); Patel and Vaishnav (1989) and Sandhikar *et al.* (1989) reported observations during the *Kharif* season that severe rust (*Puccinia arachidis*).

Summary :

The climate plays important role in determining severity of disease. The wind speed, rain and rainy days found to be most important in determining tikka disease intensity followed by relative humidity and temperature. However, relative humidity (90-100 %) and bright sunshine hours during the crop growing period were found

Table 6 : Correlation co-efficients between disease intensity of five different sowing dates with climatic factors

Sr. No.	Particulars	'r' values for groundnut diseases	
		Tikka	Rust
Climatic factors			
1.	Temperature (max.)	0.664**	0.591**
2.	Temperature (min.)	-0.550**	-0.445**
3.	Relative humidity am (%)	0.349**	0.330**
4.	Relative humidity pm (%)	-0.691**	-0.586**
5.	Wind speed (km/hr)	-0.737**	-0.634**
6.	Rainfall (mm)	0.047	0.084
7.	Rainy days	-0.261*	-0.159
8.	Evaporation (mm/day)	0.396**	0.337**
9.	Bright sunshine hours/day	0.656**	0.550**

* and ** indicate significance of value at P=0.05 and P=0.01, respectively

to be highly significant in determining rust disease intensity followed by wind speed and rainy days. The favourable climatic conditions for disease development were temperature ranged between 26 °C to 32 °C and relative humidity ranged between 61-79 per cent and bright sunshine hours of 4-6 hrs/day. The biometeorological studies showed that, earlier disease intensity also contribute in disease epidemic and development. The maximum temperature and bright sunshine hours were found to be significant and positively correlated with PDI. Minimum temperature, evening relative humidity and wind speed were found to be significant and negatively correlated. The infection severity was found to be dependent on sowing dates and the stage of the crop. The quantitatively infection was highest in early sown crop as compared to late sown crop due to climatic conditions in growing period of crop. The average infection multiplication was higher from 65 to 79 days after sowing. The vulnerable stage of groundnut crop to the tikka and rust disease incidence was active growth stage of 52-78 days after sowing.

Conclusion :

Based on the response of groundnut to different dates of sowing the conclusions are drawn.

- Among the different dates of sowing, S_3 the sowing date (6th July), recorded significantly higher and favourable growth characters.
- The climatic factors *viz*., maximum and minimum temperature, morning and evening relative humidity, rainfall and rainy days, wind speed, evaporation rate and bright sunshine hours played vital role in occurrence and development of tikka and rust diseases on groundnut crop. These climatic factors are highly correlated either positively or negatively with the occurrence, development of tikka and rust of groundnut crop.
- From the above equations the tikka and rust diseases severity can be predicted one/two weeks prior by considering mean earlier one week weekly observations of weather parameters *viz*., maximum and minimum temperatures (T max. and T min. °C), relative humidity in per cent (RH-I and RH-II), bright sunshine hours (BSS), rainfall (mm) and rainy days, wind speed (WS km/hr) and evaporation rate (mm/day).

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