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Epidemiology of necrosis virus disease caused by *Tobacco streak virus* in cotton

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Abstract
Cotton (sp.), universally known as White Gold, is an economically important cash crop of India. It is the most essential natural fiber crop in the world for textile produce. The necrosis disease of cotton caused by *Tobacco streak virus* (TSV) was frequently recorded in all cotton growing regions of India. The survey findings indicated the presence of cotton necrosis disease across all regions where cotton was cultivated, with the average incidence varying from 16.70 to 38.76 percent. An investigation conducted to determine the influence of various weather factors, including maximum and minimum temperatures, rainfall, morning and evening relative humidity, sunshine hours and the population of thrips, on incidence of necrosis disease in the susceptible cotton cultivar RCH 659. The first onset of symptom was noticed during 29th standard meteorological week (SMW) (15 July-22 July) with the disease incidence of 3.00. percent. Over a period of time, disease incidence increased and reached peak of 49.00 percent on 38th SMW which coincided with the congenial weather conditions. Thereafter the disease incidence gradually decreased to a minimum of 12.00 percent during 49th SMW (03 December to 09 December). It became evident that, the progression of the disease was closely linked to the prevailing environmental conditions and the population of thrips. In essence, the weather conditions experienced from August to September were found to be particularly conducive to both thrips movement and disease development.

Keywords: Cotton necrosis disease, *Tobacco streak virus*, weather parameters, thrips

Introduction
Cotton is the most essential natural fiber crop in the world for textile produce, accounting for about 50 percent of all fibers used in the textile industry. It is more important than the various synthetic fibers, and it is grown all over the world in about 80 countries. It is one of the agro-industrial crops which are produced in both developing and developed countries. Apart from many bacterial and fungal diseases, a new virus disease caused by *Tobacco streak virus* (TSV) is becoming a threat for cotton cultivation. TSV was first reported in tobacco (Johnson 1936) [1]. Singh and co-workers first reported TSV during 1997 in sunflower from Karnataka. Later Prasada rao *et al.* (2000) [2] and Reddy *et al.* (2002) [5] reported TSV causing sunflower necrosis disease (SND) in sunflower and peanut stem necrosis affecting groundnut in 1999 - 2000 from Andhra Pradesh. TSV is a member of the genus *Ilarvirus*, family *Bromoviridae*. The genome is tripartite with three RNAs of different length has a wide host range (Brunt *et al.*, 1996) [6], is pollen borne and transmitted by thrips (Sdoodee and Teakle, 1987; Prasada Rao *et al.*, 2003a) [7, 3]. Necrosis virus Infection in cotton often results in the development of chlorotic and necrotic spots followed by necrosis of leaf, veins, stem and squares (Sharman *et al.*, 2008; Jagtap *et al.* 2012a and Rageshwari *et al.*, 2016) [8, 12, 13]. In Tamil Nadu, Nakkeeran (AICRP report 2010) first reported the association of TSV in cotton. It has been reported to cause a maximum of 62.7 percent yield loss (Rageshwari *et al*. 2017) [14]. In the last five years, the necrosis disease caused by TSV was frequently recorded in all cotton growing regions of India. In Karnataka, meager research efforts were made in respect of necrosis virus disease of cotton. Hence, research efforts were made to understand the occurrence, symptomatology and role of epidemiological factors on the incidence of the disease.

Materials and Methods
Occurrence and distribution of *Tobacco streak virus* in cotton growing areas
Survey was carried out to assess the status of necrosis disease incidence on cotton in different parts of Kalyana Karnataka region. The observation on disease incidence, type of symptoms, stage of infection, varieties grown and presence of alternate weeds were also recorded.

Totally, four districts *viz*., Raichur, Koppal, Ballari and Yadgir were surveyed during *Kharif* 2022-2023. In each district, two taluks were selected and from each taluk two villages and in each village two cotton plots of 10 X 10 sq mt areas were observed for disease incidence. The disease incidence was calculated based on the following formula.

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants observed}}{\text{Total number of plants observed}} \times 100$$

Epidemiology of necrosis disease of cotton

The study was conducted during *kharif*, 2022-23 at ICAR-KVK, Hagari, Ballari. Cotton crop was sown on 22nd June, 2022 in 100m^2 area and followed recommended package of practice as per UAS, Raichur. Disease development was monitored at weekly interval and disease incidence was calculated as per formula mentioned above. Thrips population was recorded by using hand lenses. For recording thrips population six plants were selected, on which 3-4 leaves were seen. Meteorological observations with respect to maximum and minimum temperature, rainfall, relative humidity and sunshine hours were collected from meteorological division on weekly basis during crop growth period. Correlation co-efficient between disease incidence, thrips population and meteorological parameters were determined by Karl Pearson's formula and tested individually for their significance at 5 percent probability level by using following formula. At the end of the experiment weather parameters which are favourable for disease development was known.

$$t = \frac{r\sqrt{n-2}}{1-r^2}$$

Where,
t = test of significance
r = correlation co-efficient
n = number of observations

The rate of disease development/ unit / day was estimated according to the method given by Vander plank (1963) [17]. The apparent infection rate (r) for total period was:

$$r = \frac{1}{t_2 - t_1} \log_e \frac{X_2(1-X_1)}{X_1(1-X_2)}$$

Where,
r = rate of disease development
t_1 = date of first observation
t_2 = date of second observation
X_1 = disease severity on first observation
X_2 = disease severity on second observation

Results and Discussion

Occurrence and distribution of *Tobacco streak virus* in cotton growing areas

The survey findings indicated the presence of cotton necrosis disease across all regions where cotton is cultivated, with the average incidence varying from 16.7 to 38.76 percent. Survey conducted to assess the prevalence of TSV-associated disease in cotton has revealed that the maximum occurrence of 38.76 percent was noticed in the Raichur district. Followed by Ballari, Yadgir and Koppal exhibited incidence of 37.25, 25.67 and 16.7 percent, respectively. Highest incidence (70.00%) occurring in the hybrid Ajith 155 BG II in Betadur (Raichur district), followed by 53.00 percent in the hybrid White Gold BG II cultivated in Shankarabanda of the Ballari district (Table 1).

Table 1: Prevalence of cotton necrosis disease in four districts of Kalyana Karnataka during *Kharif* 2022-23

District	Taluk	Village	Stage of the crop	Disease incidence (%)	Mean disease incidence (%)	
Raichur	Raichur	Askihal	Vegetative	44.50	44.00	38.76
		Kallur	Vegetative	43.50		
	Lingasugur	Kuppigudda	Boll formation	30.10	32.30	
		Devar Bhupur	Vegetative	34.50		
	Devdurga	Bunkaladoddi	Flowering	21.85	22.27	
		Navilgudda	Vegetative	22.70		
	Manvi	Kurdi	Vegetative	51.25	56.55	
		Betadur	Vegetative	61.85		
Yadgir	Shorapur	Shorapur	Boll formation	20.00	19.80	25.65
		Thalavargera	Boll formation	19.60		
	Shahapur	Dhoranahalli	Flowering	36.75	31.50	
		Naykallu	Boll formation	26.25		
Koppal	Koppal	Agalkera	Boll formation	15.20	16.40	16.70
		Basapura	Flowering	17.60		
	Kushtagi	Tavaragera	Flowering	18.00	17.00	
		Inapura	Flowering	16.00		
Ballari	Ballari	Shankarabanda	Vegetative	50.50	40.00	37.25
		Asundi	Vegetative	45.50		
		Sanganakallu	Vegetative	32.00		
		Koluru	Flowering	32.00		
	Siruguppa	Sirageri	Vegetative	38.00	34.50	
		Malapura	Vegetative	31.00		

Symptomatology

During the survey, the natural symptoms of necrosis virus disease on cotton were presented here under. The preliminary symptoms began with the appearance of chlorotic lesions, which had the potential to transform into necrotic, purplish brown spots. The characteristics of these spots could vary-they could be chlorotic or necrotic, small or large. Further purplish brown spots having ring-like or irregular yellowish margin is the prominent markings of diagnostic signs. The size and pattern of these spots showed considerable variation

which join together cause drying of leaves. In severe infection symptoms spread to petiole, stem necrosis, drying of squares; terminal buds and leads to stunted plant growth with severe plant necrosis (Fig. 1).

In Tamil Nadu, severe TSV incidence has been observed in cotton-growing regions, particularly in Coimbatore and Erode districts (Rageshwari *et al.*, 2016) [13]. The results of the current investigation align with findings from previous studies.

Fig 1: Characteristic symptoms of cotton necrosis disease under field conditions

Epidemiology

In cotton, the first onset of symptom was noticed during 29th standard meteorological week (SMW) (15 July- 22 July) with the disease incidence of 3.00 percent. The incidence of the disease starts mounting from 32nd SMW and gradually increased from first week of August over a period of time and reached peak of 49.00 percent on 38th SMW due to congenial weather conditions. Thereafter the disease incidence gradually decreased to a minimum of 12.00 percent during 49th SMW (03 December to 09 December) (Table 2 and Fig. 2).

The correlation studies were made to establish the relationship between one week preceding weather parameters and the disease incidence of cotton necrosis disease. The results showed that, the disease development has significant positive correlation co-efficient with individual parameters such as, maximum temperature (0.437), morning relative humidity (0.437) and the average number of thrips (0.663). Whereas the evening relative humidity and sunshine hours are showing non-significant positive correlation. While the minimum temperature, rainfall has non-significant negative correlation on the disease development (Table 3).

Most of the time, the individual weather factor may not be the most favorable for the disease development. However, the interaction between the weather parameters has more influence on the disease progress which results in maximum disease incidence. Among the interaction between different weather parameters, the positive significant correlation was recorded by evening relative humidity and minimum temperature (0.498), rainfall (0.562) and average number of thrips (0.434). The interaction of maximum temperature with minimum temperature (-0.176), rainfall (-0.265), evening relative humidity (-0.228), minimum temperature with morning relative humidity (-0.047) and sunshine hours (-0.363), morning relative humidity with sunshine hours (-0.051) and rainfall with average number of thrips (-0.005) showed non-significant negative correlation with cotton necrosis incidence (Table 3).

The multiple linear regression of disease incidence of cotton necrosis in relation to weather parameters during 2022-23 indicated that, the regression coefficients for maximum

temperature (X_1), minimum temperature (X_2), rainfall (X_3), morning relative humidity (X_4), evening relative humidity (X_5), sunshine hours (X_6) and average number of thrips (X_7) were found to be − 0.334, − 0.597, − 0.140, 0.611, − 0.111, 5.527 and 5.406 respectively. The multiple linear regression equation was fitted to the data and the equation arrived for the weather parameters is $Y = 33.477 - 0.334 X_1 - 0.597 X_2 - 0.140 X_3 + 0.611 X_4 - 0.111 X_5 + 5.527 X_6 + 5.406 X_7$ (Table 4).

This analysis showed that, when there was increase in one unit of morning relative humidity, sunshine hours and average number of thrips the percent disease incidence was increased by 0.611, 5.527 and 5.406 respectively. Whereas increase in one unit of maximum temperature, minimum temperature, rainfall and evening relative humidity, the percent disease incidence was decreased by 0.334, 0.597, 0.140 and 0.111 units, respectively.

Shivasharanayya and Nagaraju (2003) [9] revealed the clear positive correlation between thrips population and necrosis virus incidence indicating the involvement of this agent in spread of sunflower necrosis disease. Dry weather (July–August) with moderate temperature of 30–32 °C and 55–75 percent relative humidity is conducive for thrips incidence. Higher population of thrips during *kharif* sowing was reported in sunflower *cv*. Morden (Singh 2005; Upendhar *et al*., 2006 and 2009) [10, 16, 15]. Temperature, relative humidity as well as leaf wetness played a major role in the establishment of cotton necrosis across different locations in Tamil Nadu. Results revealed that, Coimbatore (Annur) with lowest minimum temperature (22.81 °C), highest relative humidty (81.42%) and leaf wetness (23.9 h) was highly susceptible and had maximum percent TSV incidence (30.68) (Vinodkumar *et al.*, 2017) [18].

A pattern of rainy days followed by short dry spell in the month of August contributed to the rise in thrips numbers. Interestingly, this period also coincided with the flowering of *Parthenium* plants. Consequently, the thrips population synchronized with *Parthenium* flowering might be created conditions conducive to the transmission of *Tobacco streak virus*. This epidemiology studies on host range and influence of weather factors will help in disease survival and forecasting for further management implications.

A study by Prasad Rao *et al*. (2003a) [3] further supported this phenomenon. They reported that, in August and September, pollen carrying the virus settled on groundnut plants from infected *Parthenium* plants. The virus transmission occurred when thrips fed on these plants. Additionally, pre-monsoon showers created favorable conditions for the germination of *Parthenium* plants. This same scenario might explain the increased disease incidence observed in the cotton ecosystem during these months.

Table 2: Progression of cotton necrosis disease in relation to weather parameters and thrips population during *Kharif* 2022-23

Sl. No.	Standard meteorological week	Date	Temp. (°C)		RH (%)		Rainfall (mm)	Average No. of thrips	Sunshine (hrs)	Disease incidence (%)
			Max	Min	Morning	Evening				
1	26	25.06.2022 to 01.07.2022	33.74	24.04	84.71	46.86	0.00	0.04	2.63	0
2	27	02.07.2022 to 08.07.2002	31.30	23.59	91.07	55.14	0.57	1.60	1.63	0
3	28	09.07.2022 to 14.07.2022	28.57	24.40	85.67	60.17	0.33	1.54	0.57	0
4	29	15.07.2022 to 22.07.2022	32.55	23.78	86.25	49.38	0.19	2.20	2.57	3
5	30	23.07.2022 to 29.07.2022	26.94	28.14	89.00	52.14	5.29	1.94	1.82	5
6	31	30.07.2022 to 07.08.2022	29.14	24.64	95.86	60.14	23.90	0.56	3.43	5
7	32	06.08.2022 to 12.08.2022	30.64	23.67	88.43	57.00	0.71	3.50	1.99	12
8	33	13.08.2022 to 19.08.2022	31.73	23.30	86.14	50.71	0.00	4.23	3.39	24
9	34	20.08.2022 to 26.08.2022	32.70	22.66	86.00	47.00	0.79	4.05	3.63	32
10	35	27.08.2022 to 02.09.2022	31.93	23.57	96.14	52.57	3.00	4.34	3.26	33
11	36	03.09.2022 to 09.09.2022	31.59	23.00	97.14	66.43	12.71	3.80	2.53	33
12	37	10.09.2022 to 16.09.2022	30.84	23.59	88.71	57.00	0.57	5.00	4.19	40
13	38	17.09.2022 to 23.09.2022	32.23	21.19	90.29	43.57	0.00	5.60	3.04	49
14	39	24.09.2022 to 30.09.2022	30.93	22.13	95.86	62.14	9.25	4.56	2.56	45
15	40	01.10.2022 to 07.10.2022	29.81	22.41	96.00	70.29	8.45	4.02	3.74	43
16	41	08.10.2022 to 14.10.2022	30.06	20.00	90.71	68.14	3.37	4.76	4.27	37
17	42	15.10.2022 to 21.10.2022	31.71	20.41	88.57	65.29	6.23	3.86	5.27	35
18	43	22.10.2022 to 28.10.2022	31.07	3.64	96.29	38.71	0.07	3.24	3.35	33
19	44	29.10.2022 to 04.11.2022	30.54	12.59	97.71	52.57	0.93	0.50	4.66	34
20	45	05.11.2022 to 11.11.2022	31.70	16.81	96.57	33.53	0.07	0.60	3.25	28
21	46	12.11.2022 to 18.11.2022	30.37	17.03	97.07	46.36	0.00	1.02	2.90	25
22	47	19.11.2022 to 25.11.2022	29.00	16.40	78.43	43.43	0.14	0.98	2.89	18
23	48	26.11.2022 to 02.12.2022	31.5	17.58	72.71	47.14	0.00	1.22	3.91	16
24	49	03.12.2022 to 09.12.2022	30.74	17.14	71.14	37.57	0.00	0.00	4.16	12

Table 3: Correlation coefficient between weather parameters, thrips population and cotton necrosis disease

Parameters	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Y PDI	1.000							
X_1 Maximum temperature (°C)	0.437*	1.000						
X_2 Minimum temperature (°C)	-0.241	-0.176	1.000					
X_3 Rainfall (mm)	-0.033	-0.265	0.342	1.000				
X_4 Relative humidity (morning) (%)	0.437*	0.018	-0.047	0.396	1.000			
X_5 Relative humidity (evening) (%)	0.180	-0.228	0.498*	0.562**	0.314	1.000		
X_6 Sunshine hours (hrs/day)	0.491	0.383	-0.363	0.016	-0.051	0.011	1.000	
X_7 Average number of thrips	0.663**	0.375	0.277	-0.005	0.265	0.434*	0.084	1.000

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4: Multiple regression analysis for cotton necrosis in relation to weather parameters and thrips population

Location	Constant	X_1	X_2	X_3	X_4	X_5	X_6	X_7	R	R^2
ARS, Hagari, Ballari	33.477	-0.334	-0.597	-0.140	0.611	-0.111	5.527	5.406	0.888	0.788
Multiple linear regression equation										
$Y= 33.477 - 0.334 X_1 - 0.597 X_2 - 0.140 X_3 + 0.611 X_4 - 0.111 X_5 + 5.527 X_6 + 5.406 X_7$										

X_1: Max. Temp, X_2: Min. Temp, X_3: Rainfall, X_4: Morning RH, X_5: Evening RH, X_6: Sunshine hours and X_7: Average number of thrips

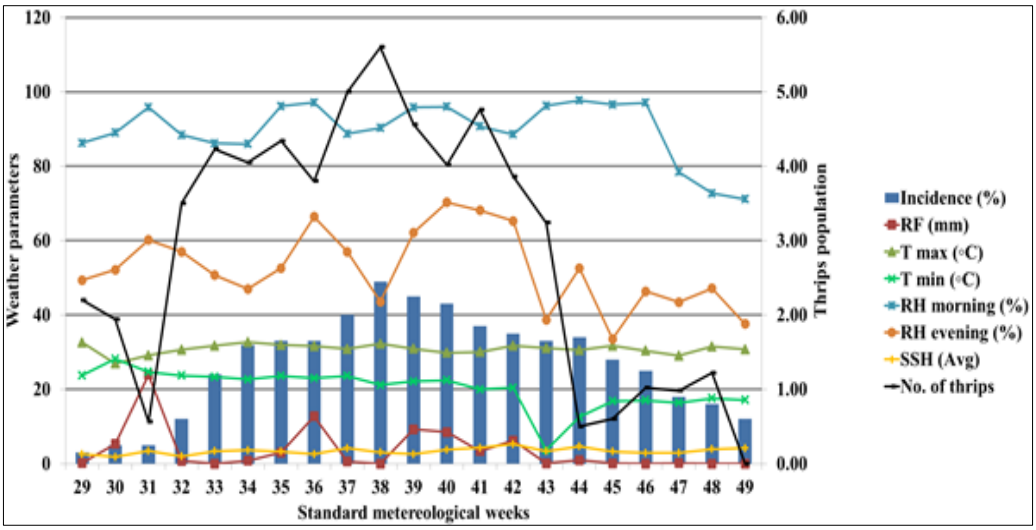

Fig 2: Influence of weather parameters and thrips population on progress of cotton necrosis disease during *Kharif* 2022-23

Conclusion

The study revealed that, weather parameters such as maximum temperature, morning relative humidity and thrips population shows significant positive correlation. While the minimum temperature, rainfall has non-significant negative correlation on the disease development. This epidemiology studies on influence of weather factors will help in disease survival and forecasting for further management implications.

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