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Temperature and rainfall influence the seasonal dynamics of thrips, *Frankliniella schultzei* and *Groundnut bud necrosis virus* incidences in tomato field

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ABSTRACT: Plant viruses depend on insect vector for transmission and they manipulate host physiology as well as vector behaviour to enhance the spread and these interactions were influenced by several biotic and abiotic factors. We found maximum temperature and dry weather (summer season) facilitated thrips (*Frankliniella schultzei*) for increased incidence of *Groundnut bud necrosis virus* (GBNV) in tomato field whereas, rainfall declined thrips population which was also affected the GBNV incidence during *kharif* and *rabi* seasons. These findings will improve our understanding on the vector-virus-host interactions in the perspectives of changing seasonal weather parameters in field condition and useful to develop any sustainable management strategies to control the disease.

Keywords: Tomato, GBNV, weather, virus disease, temperature, thrips

INTRODUCTION

Blossom thrips or tomato thrips, *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae) is an invasive, polyphagous (Kakkar *et al.*, 2012; Seal *et al.*, 2014;Palmer,1990) and found to be an emerging serious pest in India (Rabeena *et al*.,2019). Although this pest has been present over long period in several parts of India (Vijayalakshmi *et al*.,1995) not much attention was given until the recent works (Tyagi *et al.*,2017;Rabeena *et al*.,2019;Rabeena *et al*.,2020). It act as both direct and indirect pests in several host plants and indirectly transmits many plant viruses including *Tomato spotted wilt virus* (TSWV) (Wijkamp *et al*.,1995),*Groundnut ring spot virus*(GRSV) (Wijkamp *et al*.,1995;Nagata *et al*.,2004),*Tobacco streak ilarvirus* (TSV) (Klose *et al*.,1996),*Chrysanthemum stem necrosis virus* (CSNV) (Nagata, and de Aevila. 2000),*Groundnut bud necrosis virus* (GBNV) (Amin *et al*., 1981;Vijayalakshmi *et al*., 1995;Rabeena *et al*., 2019).

Tomato thrips occur in two forms (pale and dark brown) (Sakimura,1969; Riley *et al*., 2011) and both forms of *F. schultzei* had been reported as a vector of tospovirus (Mound and Marullo, 1996). We found only pale form in all the tomato growing and GBNV hot spot regions of Tamil Nadu and Karnataka states, India (Rabeena *et al*., 2019;Rabeena, 2020).

Since virus rely on its vector for movement and spread, it manipulates the vector behaviour and performance via shared host (Eigenbrode *et al*., 2018; Mauck *et al*., 2019). Several studies showed , the host suitability for the vector's growth, reproduction and longevity was influenced by the plant virus via shared host and the performance was been positive or negative or some cases neutral(Rajabaskar *et al*., 2014;Eigenbrode *et al*. 2018;Mauck *et al*., 2019).

These vector-virus-host interactions are mediated through volatile organic compound emitted from plants (Rajabaskar *et al*., 2013c). The change in the vector behaviour and the virus spread are dynamic, very complex and depends on growing stage of host at the time of inoculation (Rajabaskar *et al*., 2013b). It depends on the stage at inoculation (Rajabaskar *et al*., 2013), host plant resistance (Rajabaskar *et al*., 2013a) vector species, and virus strains (Mauck *et al*., 2019).

Besides the biotic factors weather parameters also play a major role in disease epidemiology (Krishnareddy, 2013;Islam *et al*., 2019). Any seasonal changes in the environmental factors would affect the vector-virus-host interactions (Isman *et al*., 2019). Therefore, understanding the environmental change and their impact on the disease spread is very crucial. With this view, a study was carried out to find out how the weather parameters would influence the thrips and GBNV incidences in tomato.

Table 1. Correlation analysis matrix of seasonal weather parameters with thrips *F. schultzei* and GBNV incidences (2017-2019)

		Max. Temp (ºC)	Min. Temp (ºC)	RH %	Rain fall (mm)	Wind speed (km/h)	Thrips (No./ shoot)	GBNV (%)
Summer	Max. Temp	1						
	Min.Temp	0.90	1					
	RH	0.42	0.43	1				
	Rain fall	0.17	0.13	0.32	1			
	Wind	-0.63	-0.53	-0.27	0.03	1		
	Thrips	0.84	0.65	0.32	-0.09	-0.53	1	
	GBNV	0.92	0.83	0.33	0.18	-0.42	0.90	1
Kharif	Max. Temp	1						
	Min.Temp	-0.08	1					
	RH	0.60	-0.60	1				
	Rainfall	0.24	-0.28	0.32	1			
	Wind	-0.45	0.61	-0.86	-0.49	1		
	Thrips	0.21	0.06	0.09	-0.31	0.01	1	
	GBNV	0.30	-0.61	0.59	0.46	-0.64	0.44	1
Rabi	Max. Temp	1						
	Min.Temp	0.33	1					
	RH	0.04	0.51	1				
	Rainfall	0.24	0.54	0.56	1			
	Wind	-0.70	-0.37	-0.55	-0.44	1		
	Thrips	-0.22	-0.23	-0.39	-0.75	0.27	1	
	GBNV	-0.61	-0.47	-0.35	-0.81	0.47	0.69	1
Combined Analysis	Max. Temp	1						
	Min.Temp	0.48	1					
	RH	-0.39	-0.28	1				
	Rainfall	-0.15	0.16	0.30	1			
	Wind	-0.07	0.34	-0.68	-0.15	1		
	Thrips	0.85	0.47	-0.40	-0.32	0.04	1	
	GBNV	0.65	0.42	-0.16	-0.22	-0.06	0.83	1

MATERIALS AND METHODS

Seasonal incidence of *F. schultzei* and GBNV was recorded during 2017-19 on tomato at Department of Vegetable Sciences, TNAU, Coimbatore (11.01'52°N, 76.93'26°E),India. Twenty plants were selected randomly and the incidence of GBNV and the prevalence of thrips were recorded at weekly interval starting from 7 days after transplanting. The thrips was recorded by tapping and direct counting method and the GBNV incidence was assessed by visual symptoms and the per cent disease incidence was calculated by number of infected plants out of total number of observed plants. The thrips and leaf samples were taken to the laboratory for species and virus confirmation respectively as reported in our previous works (Rabeena *et al*., 2019; Rabeena *et al*., 2020).

Weekly counts were correlated with meteorological data such as maximum temperature (T_{max}), minimum temperature (T_{min}), relative humidity (RH), rainfall and wind speed obtained from the automatic weather station installed at Tamil Nadu Agricultural University, Coimbatore.Correlation and regression analysis were carried out using SPSS statistics ver.17.0 to assess the relationship between seasonal incidence of *F. schultzei* and GBNV in tomato.

RESULTS AND DISCUSSION

Seasonal incidence of *F.schultzei* (no./shoot)and GBNV (%) have been observed in tomato field from 2017 to 2019 (summer, *kharif* and r*Rabi* seasons). Three years seasonal data were pooled and graphically presented (Fig.1). The results showed thrips and GBNV incidences were higher in summer, medium in *kharif* and low in *rabi* season and the temperature and rainfall had influenced the seasonal dynamics in the thrips occurrence which in turn affected GBNV incidence in the tomato field (Fig.1).

During summer season (SMW 6-18) a positive correlation coefficient (r) of 0.84 between thrips and maximum temperature indicates when temperature goes higher thrips population will be increased.GBNV incidence was increased with increasing temperature (r=0.92).There was a positive correlation between thrips and GBNV incidences (r=0.90), (Table 1). A negative correlation coefficient (r = - 0.53) was observed between thrips and wind speed (km/h) which indicates slower the wind speed more will be the thrips population on the plant. In this season, the average temperature (34.8;22.5°C),rainfall (5.3mm),RH (84.2%) ,wind speed (5.9km/h), average thrips population (1.7/shoot) and GBNV incidences (31.4%) were observed.

Sixty seven per cent of total variation independent variable (number of thrips per plant) that occurred during summer season was explained by a regression model with an independent variable, maximum temperature (F=22.5 ; df : 12; P= <0.001) and regression model (y=0.42x-12.75) showed one unit increase in temperature will increase 12.75 number of thrips per plant (Fig.2).

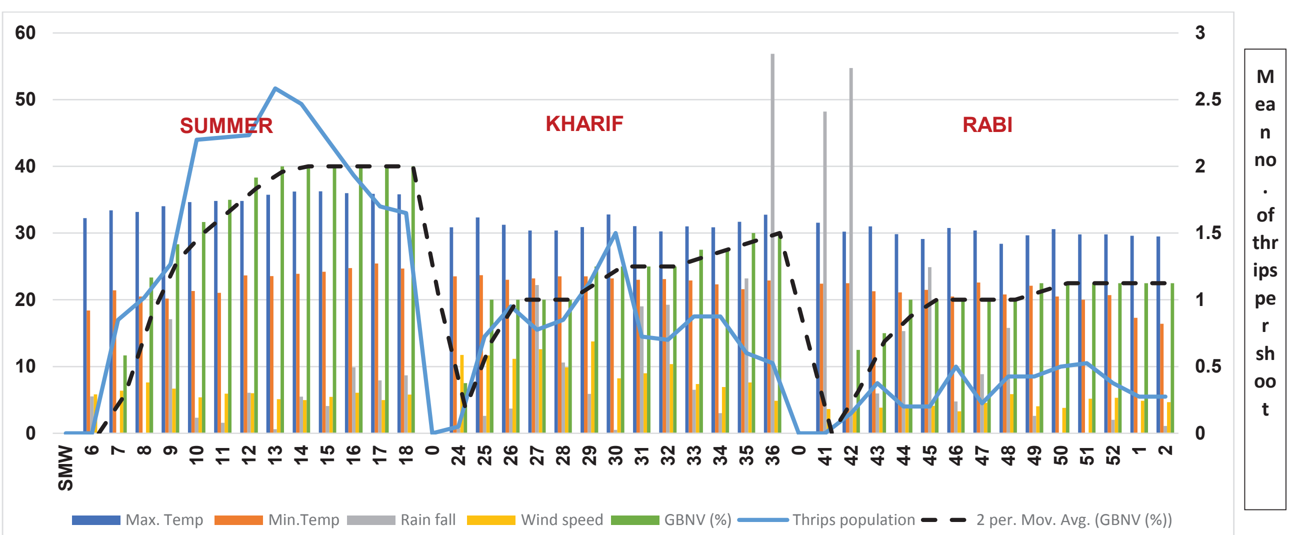

Fig.1.Seasonal dynamics of *F. schultzei* and GBNV incidences in relation to weather parameters in tomato field (2017-2019);The X axis shows Standard Meterological Weeks (SMW);Primary Y axis shows values of independent variables (Max. Temp (°C),Min.Temp (°C), Rainfall (mm), Wind speed (km/h), GBNV (%) ; Secondary Y axis shows mean no.of thrips/shoot; Solid blue line indicates seasonal dynamics of thrips;doted dash indicates seasonal dynamics of GBNV. The data shown here is pooled mean of three years (2017-2019).

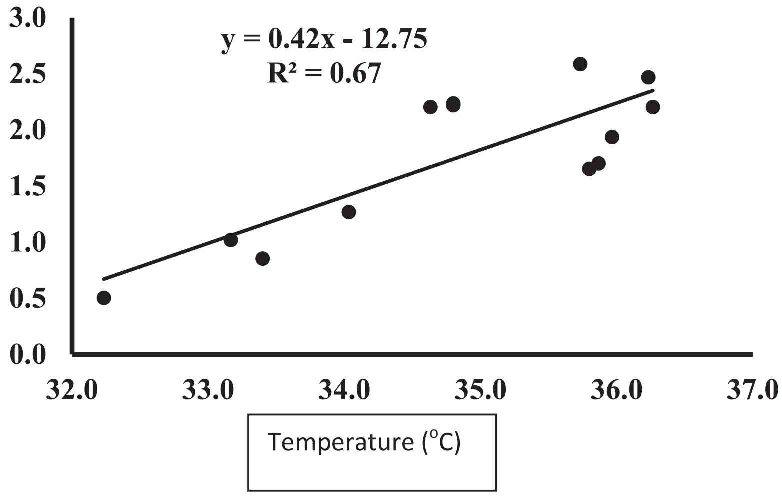

Fig. 2. Regression analysis between Max.Temp and thrips (Summer)

While keeping GBNV incidence as independent variable (r^2=74;F=32.0 ; df : 12; P= <0.001) and the regression equation (y=14.18x + 7.29) explained an unit increase in mean number of thrips population will likely to increase 7.29 per cent of GBNV incidence under dry weather condition (Fig.3).

During *Kharif* season (SMW 24-36), thrips incidence was negatively correlated with rainfall (r= - 0.31). GBNV incidence was also negatively correlated with minimum temperature (r= -0.61) and positively with RH (r = 0.59), (Table 2).In this season, the following mean weather parameters *viz*., temperature (31.3;23.0^{0}C), rainfall (13.4mm), RH (84.4%), wind speed (9.6km/h) and mean thrips population (0.8/shoot) and mean GBNV incidences (23.3%)were observed. Rainfall was negatively correlated with thrips incidence and found to be non-significant (r^2=0.01;F=1.16 ; df : 12; P= 0.30); (Fig.4) and the GBNV incidence was positively correlated with thrips and found non-significant (r^2=0.2;F=2.57 ; df : 12; P= 0.13).

In *rabi* season(SMW 41-2), we found the independent variable *viz*.,the average temperature (30.0; 20.7^{o}C), rainfall (13.6mm), RH (88.4%), wind speed (4.3km/h) and dependant variable such as average thrips population (0.3/shoot) and average GBNV incidence (18.8%).Where the rainfall and RH were higher, and temperature was lower when compared to summer. The thrips population and GBNV incidence were lower than previous season (Fig.6). Correlation coefficient of thrips incidence was negative with rainfall (r = - 0.75) and GBNV incidence was positively correlated with thrips (r = 0.69) and negatively correlated with rainfall (r = - 0.81).

In *rabi* season also same trend as that of *kharif* season where, the regression model showed that rainfall had affected the thrips population (r^2=0.43;F=9.20 ; df : 12; P= 0.01) and regression equation (y= - 0.005x + 0.39) showed that one unit increase in rainfall will decline 0.39 mean number of thrips per shoot (4). In turn it affected the GBNV incidence where the regression analysis of dependant variable as thrips and independent variable as GBNV demonstrated with a model (r^2=0.21;F=3.16 ; df : 12; P= 0.1) and regression equation (y= - 0.01x + 0.15). Combined seasonal correlation analysis showed, thrips incidence was positively correlated with maximum temperature (r = 0.86) and found to be highly significant and negatively correlated with rainfall (r = 0.65) and found to be non-significant whereas, GBNV incidence was positively correlated with thrips incidence (r = 0.82) and maximum temperature (r = 0.65).

During both *kharif* and *rabi* seasons the rainfall had negative correlation with thrips population which in turn affected the GBNV incidence whereas mostly during summer seasons maximum temperature had positive correlation with thrips and GBNV incidences. The wind velocity also showed negative correlation with thrips population.

The increase in temperature and decrease in rainfall during summer season favours the thrips activity to spend more time on the plant for virus inoculation specifically viruliferous thrips because healthy plants might have attracted viruliferous thrips through behaviour manipulation which had been evidenced from previous works (Ingwell *et al*.,2013;Rajabaskar *et al*.,2014;Eigenbrode *et al*.,2018;Mauck *et al*.,2019). The performance of the viruliferous or non viruliferous vector on healthy or infected hosts is very complex and vary with plant resistance, host phenology and bio

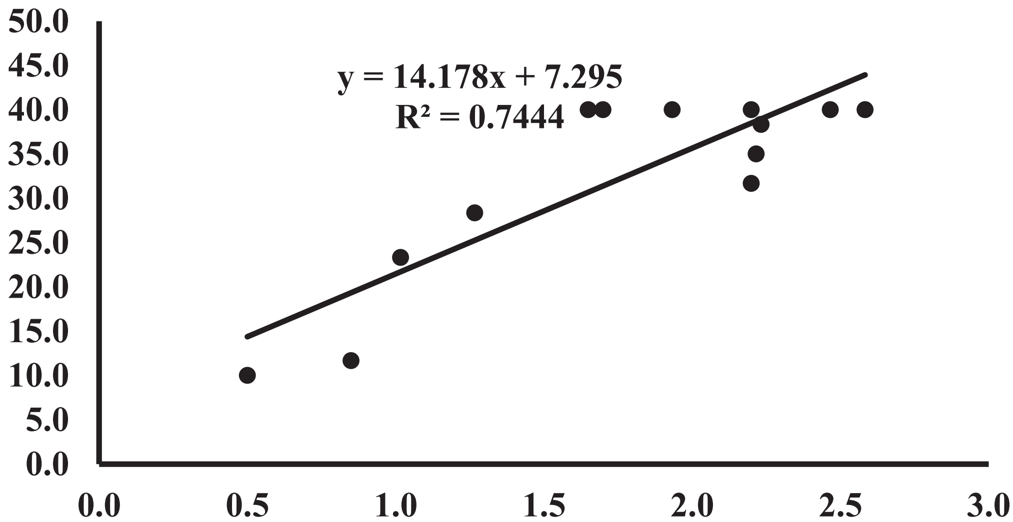

Fig. 3. Regression analysis between thrips and GBNV (Summer)

chemical factors as well as vector species and virus strains (Rajabaskar *et al*.2013;Eigenbrode *et al*.,2018). These kind of interactions are coevolved among virus, vector and plant to enhance the disease spread under field conditions (Roosien *et al*.,2013).We found that success of these tripartite interactions also depends on the prevailing weather factors especially temperature and rainfall. Because warm weather is required for successful dispersal of thrips under field conditions (Kirk,1997;Moresello *et al*.2008) which would have increased the GBNV incidence during summer season.

During both *kharif* and *rabi* seasons GBNV incidences were decreased as the thrips population was lowered due to more precipitation. This may be due to direct effect of rain on the thrips population which would have prevented successful dispersal and establishment (Kirk,1997). Interestingly, we found only adult thrips population on the plant and was also very low (1-3 numbers/plant) where, the adults are associated for virus transmission instead using the host for reproduction and establishment such a condition makes any *in situ* control measure for vector control would be very challenging. The incidence of GBNV was greater at the later stage of the crop this may be due to time interval between virus inoculation and disease expression.

Most of the plant viruses depend on insect vector for transmission and they manipulate host physiology as well as vector behaviour to enhance the spread (Eigenbrode *et al*.,2018;Mauck *et al*.,2019) and these interactions were influenced by several biotic and abiotic factors (Krishnareddy,2013;Islam *et al*.,2019). When changes in the seasonal weather factors (temperature, rainfall, wind and humidity) showed high influence on vector-virus-host interactions (Islam *et al*., 2019) and disease expression (Ghoshal and Sanfaçon, 2015). We found maximum temperature and dry weather (summer season) facilitated thrips (*F. schultzei*) for increased occurrence of GBNV in tomato field whereas, rainfall declined thrips population which was also affected the GBNV incidences as evidenced during *kharif* and *rabi* seasons. These findings will improve our understanding on the vector-virus-host interactions and useful to develop any sustainable management strategies to control the disease.

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