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Seasonal phenology and pheromone trap catches South American tomato leaf miner of *Tuta absoluta* (Lepidoptera: Gelechiidae) in open field tomato under sub-tropical climatic conditions in Andhra Pradesh

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Abstract
In last 25 years, at least 10 species of insect and mite pests have invaded India. These includes, the American serpentine leafminer, *Liriomyza trifolii* (Burgess) in 1990-91, the coffee berry borer, *Hypothenemus hampei* (Ferrari) in 1990, south American tomato moth, *Tuta absoluta* (Meyrick) in 2014 and the western flower thrips, *Frankliniella occidentalis* (Pergande) in 2015. Field experiment was conducted to determine the influence of weather parameters on trap catches and incidence of *T. absoluta* during *rabi*, 2016-17 in farmers' field at Kalikiri in Chittoor district, Andhra Pradesh. Maximum temperature, minimum temperature and morning relative humidity showed non-significant positive association, while evening relative humidity (r = -0.618) and rainfall (r = -0.467) showed significant negative association with moth catches of *T. absoluta*. All weather factors displayed non-significant association with leaf infestation. Maximum (r = 0.840) and minimum (r = 0.750) temperature showed significant positive relation with fruit infestation and evening relative humidity (r = -0.537) have significant negative association. The weather parameters, together accounted for 72.80 per cent (R^2 = 0.728) of the total variation in trap catches. Pheromone trap catches showed significant positive association with leaf infestation of *T. absoluta* in tomato.

Keywords: *Tuta absoluta*, weather parameters, invasive, Surveillance South American tomato leaf miner

Introduction
The invasive pest, *T. absoluta* (Meyrick) (Lepidoptera: Gelechiidae) that is known by the common names of South American tomato leaf miner and South American tomato pinworm, is a oligophagous pest on solanaceae family, especially tomato, and is considered to be a serious threat to tomato production in Mediterranean region and also sub tropical regions. This pest cause's 50-100% yield reduction on tomato crops and also potato, brinjal crops. South American tomato moth, *T. absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a devastating pest of tomato that has undergone a rapid expansion since its first report from India and has the potential to occur throughout the year in the tomato ecosystem [9, 13]. The larvae of this pest feed on the leaf mesophyll and also damage tomato shoot, flower bud, flowers and fruits, on which the black frass is visible.

Presently, the pest has spread to other states like Maharashtra, Tamil Nadu, Andhra Pradesh, Telangana, Gujarat, Delhi, Chhattisgarh etc. Application of chemical insecticides is the most commonly used practice for suppression of *T. absoluta* infestations. Though the pesticides used against this pest give satisfactory control, extensive use of insecticides may lead to the development of insecticide resistance [12, 7].

In general, 20 to 30% yield loss is caused by this pest and may result in 100% damage, if timely management interventions are not followed. In order to avoid or at least to reduce the indiscriminate use of insecticides in the infested fields, it is essential to develop an alternative method for monitoring the pest population of *T. absoluta*. Pheromone trap data gave early warning of the infestation and also alert the farmers to go for the integrated management practices at low level of population before they become serious. The usage of pheromone traps seems to be the most ideal alternatives in managing the pest.

The mode action of the sex pheromones that interfere with reproduction process of the insect offers a non-traditional way to manage lepidopteron and other insect species. These pheromones are species specific, highly selective, non-toxic and safe to humans and animals. The usage of pheromone traps for trapping of insects is proved to be a best management practice to check the pest population under field conditions [5].

Seasonal activity of insect pest population of tomato was quite complex and highly influenced by abiotic factors in their abundance and distribution. Seasonal incidence gave information about incidence levels in field to take up correct and timely management practices to reduce the pest incidence in the infested fields. Seasonal incidence gave information in development of forecasting models for Invasive insect pests in various crops *i.e*., Maize, tomato and cotton etc.

Materials and Methods

A Field experiment was conducted during *rabi*, 2016 in farmer's field at Kalikiri in Chittoor (Andhra Pradesh). Sweakar hybrid was transplanted in month of December in 0.2 ha with spacing of 60 × 60 cm. The per cent leaf and fruit borer infestation were recorded at the weekly interval during *rabi* on 50 randomly tagged plants in the entire field during the period of experimentation. Delta traps were installed at crop canopy level with two milligram septum replaced for every 30 days. Delta traps were installed at 30 days after transplanting. The correlation studies were carried out between trap catches and damage levels. In addition to that, the correlation between weather factors and moth catches were also worked out. SPSS package tools were used in analysis of primary data of an experiment.

Data analysis: The experiment was conducted in a Randomized plot design. Statistical analysis was carried out using analysis of variance (ANOVA) [10].

Evaluation and monitoring

For more accurate evaluation of this pest's population dynamics, number of moths trapped was recorded on the daily basis and every month we determined the percentage of active infestation on samples of 50 randomly selected plants per site, as well as the mean number of live larvae per plant.

Results and Discussion

Relationship between trap catches of *T. absoluta* and the weather parameters during *rabi*, 2016-17.

Moth population was monitored starting from transplanting using sex pheromone traps (PCI Delta sticky traps). Pheromone traps were installed 0.5 m above ground level and adjusted to canopy height at weekly interval. Sex pheromone dispensers were renewed every four weeks and the number of moths captured per trap was recorded weekly during crop season.

The correlation studies were carried out between the trap catches and preceding and existing month selected weather parameters *viz.*, maximum and minimum temperature, morning and evening relative humidity, rainfall, sun shine hours and wind velocity and the results were presented in Table.1 and Fig. 1. Maximum (r = 0.434) and minimum temperature (r = 0.146) have non-significant positive association with *T. absoluta* moth catches. Morning and evening relative humidity showed a non-significant positive and significant negative association with moth catches of *T. absoluta* having correlation coefficient (r) values of 0.134 and -0.618, respectively. Rainfall (r = -0.467) exhibited significant negative association with trap catches. The sunshine hours showed non-significant positive association and wind velocity showed non-significant negative association with trap catches of *T. absoluta* having correlation coefficient values of r = 0.44 and r = -0.052, respectively. The results of present study were in conformity with reports of Bagmare *et al*. (1995), Abbes and Chermiti (2012) and Ata and Meghed [2] Abbes and Chermiti [1], Sateesh *et al*. [11], Basavaraj *et al*. [4] and Nandini and Mohan [8] suggested that the performance of pheromone traps and lures will be influenced by the weather parameters. When the data was subjected to multiple linear regression analysis data presented in Table 2 and it revealed that weather parameters contributed to 72.80 per cent (R^2 = 0.728) of the total variation in trap catches.

Relationship between levels of field incidence of *T. absoluta* and weather parameters during *rabi*, 2016-17.

Correlation analysis carried out between leaf and fruit infestation with abiotic factors was presented in Table 3 and Fig. 2. The leaf infestation showed non-significant positive association with maximum (r = 0.352) and minimum (r = 0.205) temperature, morning relative humidity (r = 0.160) and sunshine hours (r = 0.212) while non-significant negative association with evening relative humidity (r = -0.432), rainfall (r = -0.381) and wind velocity (r = -0.089). Maximum (r = 0.840) and minimum (r = 0.750) temperature showed significant positive association with fruit infestation. Morning relative humidity (r = -0.392) showed non-significant negative association and evening relative humidity (r = -0.537) displayed significant negative association with fruit infestation. However, rainfall (r = -0.154) and wind velocity (r = -0.217) exhibited non-significant negative association with fruit infestation. On contrary, sunshine hours (r = 0.267) showed non-significant positive association with fruit infestation. The results of present investigation conformity with reports of Ata and Meghed [2] and Nitin *et al*. [9] concluded that weather parameters influence with leaf and fruit infestation.

Relationship between Pheromone trap catches of *T. absoluta* and Levels of field incidence during *rabi*, 2016 - 17.

There was a linear increment in the number of captured moths on tomato crop. The number of moths captured ranged from 03 to 352 in the field conditions. The larvae of the tomato leaf miner inflicted a heavy damage on young tomato plants. As a result, young plants died before flowering. The pest is likely to cause heavy losses to tomato crop on an unprecedented scale in India.

The correlation analysis carried out between the trap catches and per cent leaf and fruit infestation recorded during *rabi*, 2016-17 and is presented in Table 5 and Fig.3. The trap catches showed significant positive association with leaf infestation (r = 0.722) while it exhibited non-significant positive association with fruit infestation (r = 0.368) of *T. absoluta*. The results were strengthened by Nitin *et al*. [9] and Cocco *et al*. [5] and Lazgeen *et al*. [6] in tomato grown in the open field conditions. During multiple linear regression analysis revealed that pheromone trap catches were significantly positively contributed for 73.90 per cent (R^2 = 0.739) from total infestation of *T. absoluta* which was recorded from 50 randomly selected and tagged plants in

tomato field.

Ecology

Insect pest population of tomato was quite complex and highly influenced by ecological factors such as maximum and minimum temperature, morning and relative humidity, rainfall, sunshine hours and wind velocity in their abundance and distribution. Seasonal incidence gave information about incidence levels in field to take up correct and timely management practices to reduce the pest incidence in the infested fields.

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Table 1: Correlation matrix between weekly trap catches of *T. absoluta* and weather parameters during *rabi*, 2016-17

		Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Moth catch/trap/week	Y		0.434	0.146	0.134	-0.618**	-0.467*	0.440	-0.052
Maximum temperature (˚C)	X_1			0.787**	-0.414	-0.782**	-0.253	0.293	-0.310
Minimum temperature (˚C)	X_2				-0.215	-0.275	0.126	-0.198	0.015
Morning relative humidity (%)	X_3					0.393	0.117	-0.074	0.531*
Evening relative humidity (%)	X_4						0.521*	-0.621**	0.367
Rainfall (mm)	X_5							-.590**	0.596**
Sunshine hours (hrs/day)	X_6								-0.395
Wind velocity (km/hr)	X_7								

* Significant at 0.05 level. ** Significant at 0.01 level.

Table 2: Multiple linear regression analysis of pheromone trap catches of *T. absoluta* in tomato and selected weather parameters during *rabi*, 2016-17

	Variable	Partial regression coefficient	Standard error	t- value
X_1	Maximum temperature (°C)	-0.521	2.811	-0.185
X_2	Minimum temperature (°C)	0.591	1.878	0.314
X_3	Morning relative humidity (%)	1.207	0.521	2.315
X_4	Evening relative humidity (%)	-0.888	0.689	-1.289
X_5	Rainfall (mm)	-0.658	0.536	-1.227
X_6	Sun shine hours (hrs/day)	-0.599	1.289	-0.465
X_7	Wind Velocity (km/hr)	0.567	3.140	0.860

Multiple linear regression equation

$Y = -40.203 – 0.521 X_1 + 0.591 X_2 + 1.207 X_3 – 0.888 X_4 – 0.658 X_5 – 0.599 X_6 + 0.567 X_7$

Y = Moth catches /trap/week

Intercept = -40.203

$R^2 = 0.728$

Table 3: Correlation of weekly abiotic parameters with per cent leaf and fruit infestation of *T. absoluta* in tomato during *rabi*, 2016-17

Parameters	Temperature		Relative humidity		Rainfall	Sunshine hours	Wind velocity
	Maximum	Minimum	Morning	Evening			
Per cent Leaf infestation (%)	0.352	0.205	0.168	-0.432	-0.381	0.212	-0.089
Per cent Fruit infestation (%)	0.840**	0.750**	-0.392	-0.537*	-0.154	0.267	-0.217

* Significant at 0.05 level.** Significant at 0.01 level.

Table 4: Multiple linear regression analysis of selected weather parameters with leaf and fruit infestation of *T. absoluta* in tomato during *rabi*, 2016-17

Parameter	Multiple linear regression equation	R^2- value
Per cent Leaf infestation (Y_1)	$Y = 51.897 – 3.526 X_1 + 2.616 X_2 + 1.321 X_3 – 1.526 X_4 – 0.772 X_5 – 0.624 X_6 – 1.763 X_7$	0.540
Per cent Fruit infestation (Y_2)	$Y = – 362.900 + 10.509 X_1 – 1.616 X_2 – 0.852 X_3 + 1.968 X_4 – 0.754 X_5 + 3.180 X_6 + 7.131 X_7$	0.894

Y_1 = Per cent leaf infestation from randomly tagged plants

Y_2 = Per cent fruit infestation from randomly tagged plants

Table 5: Correlation between weekly pheromone trap catches and per cent leaf and fruit infestation of *T. absoluta* in tomato during *rabi*, 2016-17

Parameter	Per cent Leaf infestation (%)	Per cent Fruit infestation (%)
Moth catch/trap/week	0.722**	0.368

** Significant at 0.01 level.

Multiple linear regression equation:

$Y = 0.815 + 0.604 X_1 + 0.093 X_2$

Y = Moth catch /trap/week

X_1 = Per cent leaf infestation from 50 randomly tagged plants X_2 = Per cent fruit infestation from randomly tagged plants

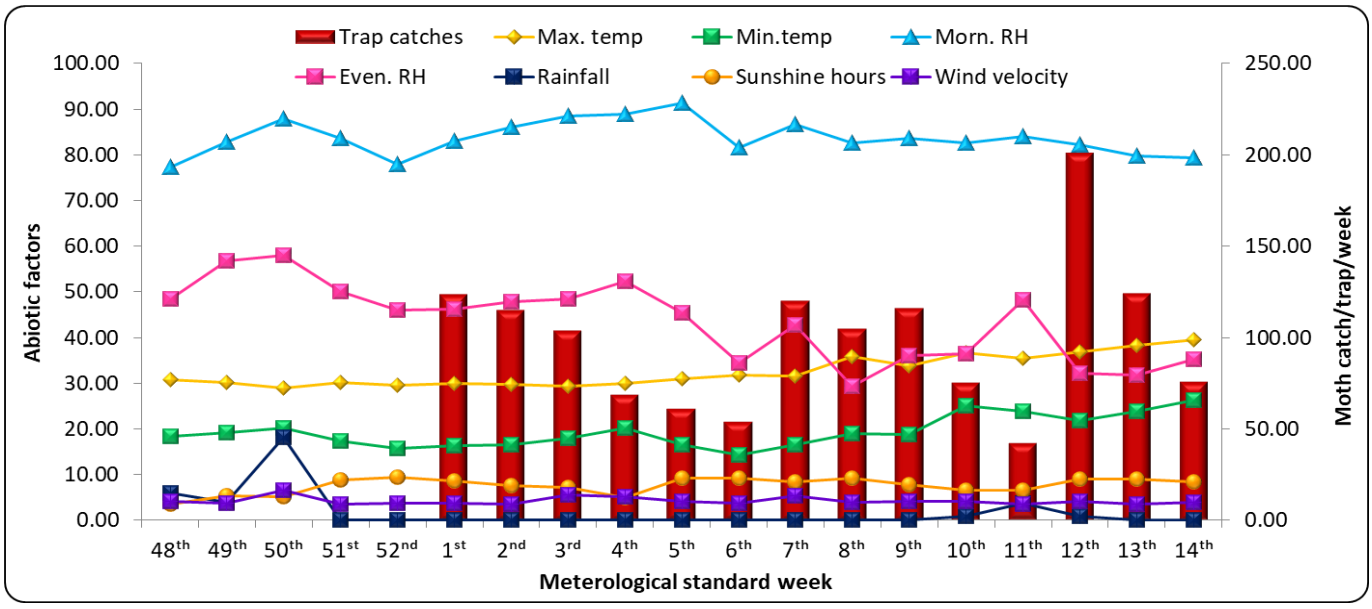

Fig 1: Influence of standard week wise abiotic factors on pheromone trap catches of *T. absoluta* in tomato during *rabi*, 2016-17

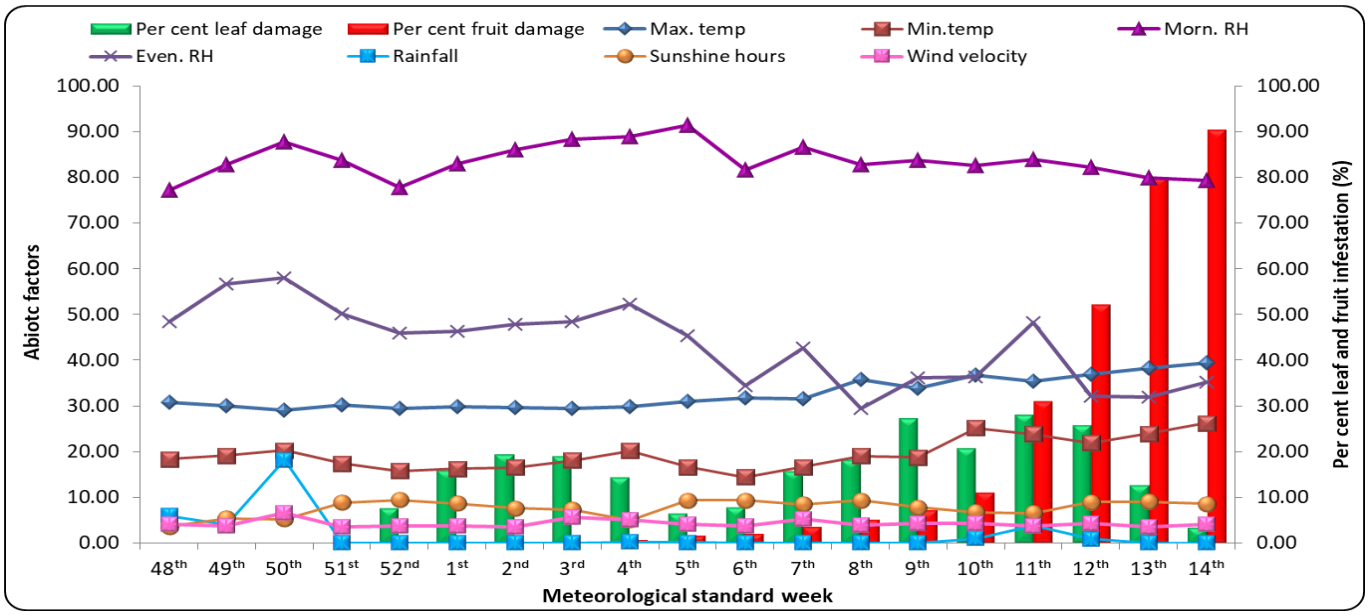

Fig 2: Influence of standard week wise abiotic factors on leaf and fruit infestation of *T. absoluta* in tomato during *rabi*, 2016-17

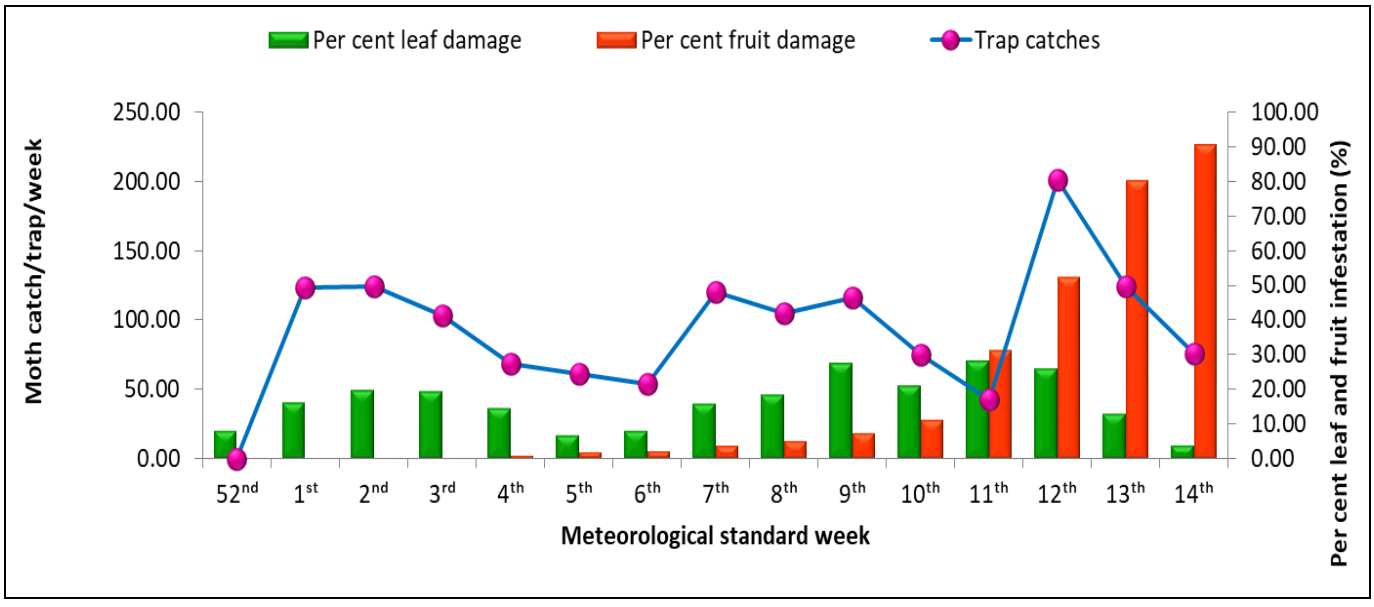

Fig 3: Influence of moth catches of *T. absoluta* on leaf and fruit infestation in tomato during *rabi*, 2016-17

Conclusion

The study revealed that evening relative humidity and rainfall have significant individual effect on moth catches where in, a negative association with moth catches of *T. absoluta* during *rabi* season. Per cent leaf and fruit infestation showed significant positive association with maximum and minimum temperature, while significant negative association with evening relative humidity. The trap catch was increased with leaf and fruit damage. The highest infestation *T. absoluta* in tomato leaves was recorded during 9th and 11th standard week, while maximum fruit damage was recorded during 14th standard week under the influence of pheromone traps in field. The leaf infestation showed significant positive association with trap catches of *T. absoluta* in tomato.

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