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Incidence of tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Telangana (India)

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Abstract
A study was taken up to know the incidence of Tomato pinworm, *Tuta absoluta* in summer and *kharif* seasons of 2015-16 and 2016-17 in different districts of Telangana. Results revealed that leaf and fruit damage were more in summer crop compared to *kharif* crop, in general. During *kharif* maximum leaf damage was lower (11.7%) with no fruit damage. Roving surveys amongst different villages of six districts indicated infestation levels of 5-90% with maximum at Mahboobnagar and Adilabad districts and minimum in Medak and Waranagal districts. Trap catches were also higher in summer season (4-90 adults/trap/week) over *kharif* (0-50 adults/trap/week) season. Correlative analyses of leaf and fruit damage during summer with weather variables indicated positive association with maximum and minimum temperature, evening relative humidity, rainfall and rainy days, sunshine hours, wind speed and evaporation and negative association with morning relative humidity.

Keywords: Tomato, pinworm, *Tuta absoluta*, survey, seasonal incidence

1. Introduction
India is the second largest producer, accounting for 11.2% of the world production and the second largest in terms of acreage accounting for 18.27% of the world acreage [1]. Tomato leaf miner or South American tomato leaf miner or tomato pin worm, *Tuta absoluta* (Meyrick) (Lepidoptera Gelichiidae) is a serious pest on tomato (*Solanum lycopersicum*) in several countries in Latin America and Mediterranean basin [2]. The aggressive nature of the pest, multivoltine character, short generation time, high biotic potential and increased resistance to insecticide use are the reasons for its key pest status in the new localities [3, 4]. It is a new invasive pest and established in the Malnad and Hyderabad-Karnataka Regions of Karnataka, India [5] and entered Telangana during November 2014. Percent crop loss to an extent of 50-60% in tomato were reported [6].

The primary host of *T. absoluta* is tomato, but it has been reported on other secondary hosts like brinjal (*Solanum melongena* L.), pepper (*Capsicum annuum*), potato (*Solanum tuberosum* L.), sweet pepper (*S. muricatum* L.) and tobacco, *Nicotiana tabacum* L. [7-9]. It has also been reported from several Solanaceous weeds, including *Datura ferox* L., *D. stramonium* L. and *N. glauca* Graham [10, 4, 11, 12]. It causes reductions in yield and fruit quality, 50% to 100% loss in either greenhouses or fields. Plants are damaged by direct feeding on leaves, stems, buds, calyces, young fruit, or ripe fruit and by the invasion of secondary pathogens which enter through the wounds made by the pest [2].

Intensive spread and dissemination of tomato leaf miner should be correlated with fruit importation and commercialization [13]. One of the possible pathways for a long distance dissemination of *T. absoluta* could be through a packaging material (boxes) coming from infested countries [14]. Being an *r*-selected and multivoltine species [9] and due to its rapid population growth, potential dispersal through environment and expressed resistance to insecticides [4] this pest has been classified as the most serious threat for tomato production worldwide. Hence its occurrence in India, in the localities surveyed is a matter of concern. The adults can fly actively for several kilometers, which allows for short distance spread (field-to-field, field to glasshouse and vice versa) [15].

Management of the tomato pin worm is difficult because 1) its developmental cycles depend on environmental conditions, 39.8 days at 19.7 ^{0}C and 23.8 ^{0}C days at 27.1 ^{0}C [12] which are very much present in major tomato growing areas of India to facilitate the pest to complete 10

to 15 generations per year; 2) Existence of suitable Solanaceous host plants in central and southern India makes establishment and spread of transient populations possible; 3) In addition to crop plants, Solanaceous weeds could serve as host reservoirs which do exist in India; and 4) Difficulty in adaptation of area wide management programmes due to numerous small holdings.

Population development of *T. absoluta* under simulated glass house conditions indicated that temperature range between 19 and 23 °C is the most favourable temperature for moth development. Temperatures of 10 °C and below proved fatal for moth development. However, this could form the basis of a control programme for sterilizing the glasshouse following an outbreak of moths [16, 17]. A zoophytophagous mirid bug, *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae) was recorded as predator on eggs and early larval stages under field conditions. Studies on this pest in Rajendranagar area and different districts of Telanagan State are scarce and hence the present study was carried out to know the incidence and damage levels in *kharif* and summer seasons.

2. Materials and Methods

In order to ascertain the incidence of *T. absoluta*, different studies were carried out in the following ways

2.1 Weekly data counts in the research plots

To study the pest incidence levels in Rajendranagar, weekly data counts on the pest were taken in tomato plots at the Vegetable Research Station, Rajendranagar. The crop was sown in the *kharif* season of 2015 in ten plots of 40 Sq.m size each and counts on pest population were taken on 10 randomly selected and tagged plants at weekly intervals from 30 days after transplanting till final harvest. Data on no. of live mines/five leaves /plant, no. of shoot damage/plant, no. of fruit damage/plant were recorded.

2.2 Roving Surveys in farmers' fields of Shamshabad and Moinabad districts

Roving surveys were carried out in farmers' fields of Shamshabad and Moinabad mandals during *kharif* 2015 to understand the incidence levels. In each district an area of 1 ha in areas where the pest was highly prevalent was identified and counts were taken on 10 randomly selected and tagged plants at weekly intervals from 30 days after transplanting till final harvest. Data on no. of live mines/five leaves /plant, no. of shoot damage/plant, no. of fruit damage/plant were recorded.

2.3 Installation of traps in the farmers' fields in ten villages of Shamshabad and Moinabad districts

WOTO traps with sex pheromones were installed in farmers' fields in ten villages of Shamshabad and Moinabad mandals at the rate of 4 traps per acre during *kharif* 2015 to understand the occurrence levels of the pest. The lures were changed every 20 days till the counts were taken. Data on no. of live mines/five leaves /plant, no. of shoot damage/plant, no. of fruit damage plant were recorded.

2.4 Roving survey in six districts of the state

WOTO traps with sex pheromones were installed in farmers' fields of Mahboobnagar, Rangareddy, Adilabad, Warangal and Medak districts at the rate of 4 traps per acre during *kharif* 2015 to understand the occurrence levels of the pest. The lures were changed every 20 days till the counts were taken. Data on no. of live mines/five leaves /plant, no. of shoot damage/plant, no. of fruit damage/plant were recorded.

2.5 Impact of weather parameters on the pest

Data on weather parameters viz., temperature, relative humidity and rainfall were also recorded during the study to understand its impact on the pinworm. The weather parameters were taken from Agro met weather Station, ARI, Rajendranagar, Hyderabad.

2.6. Statistical analysis

Correlation analysis was used to know the impact of weather parameters on insect population.

3. Results and Discussion

3.1 Weekly data counts in research plots

3.1.1 Leaf damage

Results showed that leaf damage by *T. absoluta* in *kharif* was lesser than in *rabi*. Damage started in the third week of July both the years and ranged from 3.8 to 12.8 % in the first year and 2.8 to 10.5% in the second year (Fig.1.). In *rabi*, leaf damage started from second week of March (43.89%) and recorded a steady increase till it reached a peak at the end of May (90.13%) both the years. However, there was a sudden dip in mid-May when the damage dipped from 80.50 % in May first week to 77.99% in mid May. It increased again to 90.12% in May last week (Fig.2). 86% infestation on leaves was reported by *T. absoluta* on tomato in *rabi* season in Chittoor dt of Andhra Pradesh [18].

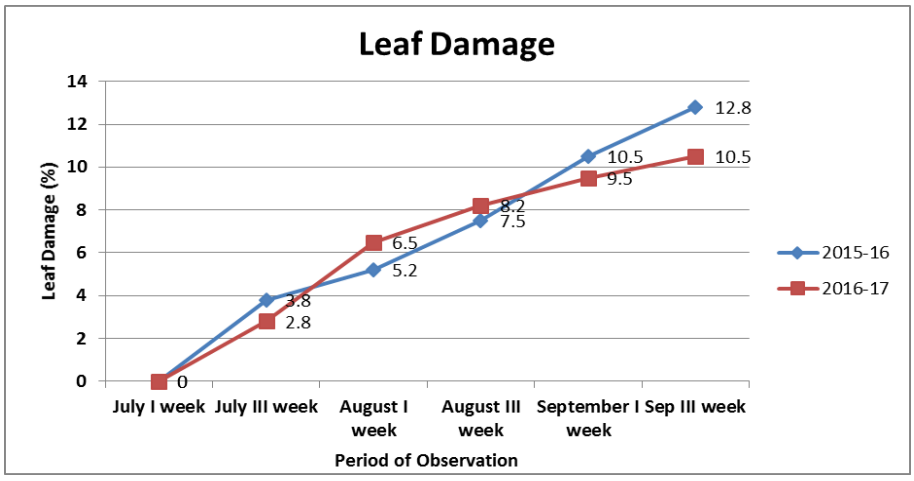

Fig 1: Leaf damage caused by *T. absoluta* in tomato in *kharif* 2015-16 and 2016-17

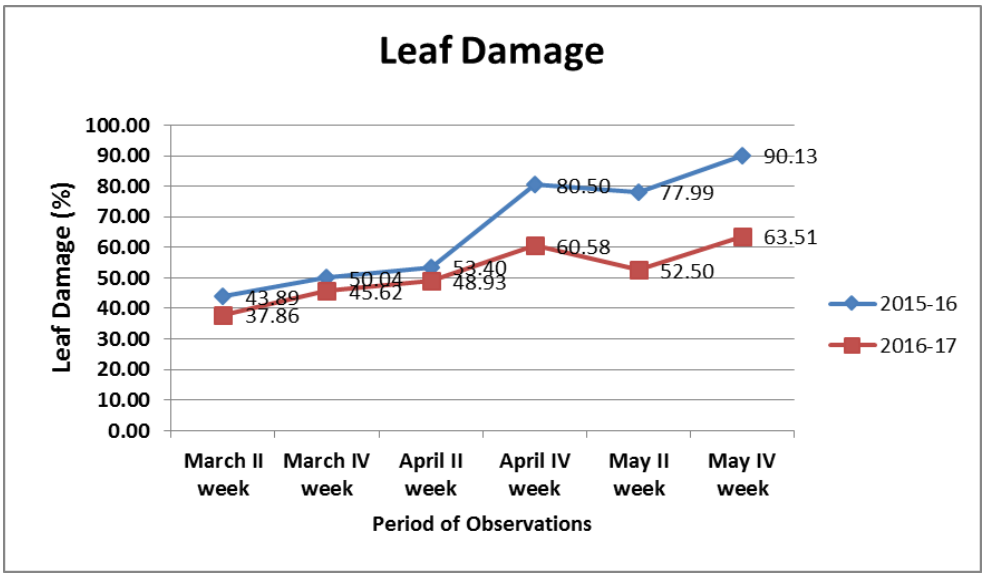

Fig 2: Leaf damage caused by *T. absoluta* in tomato in *rabi* 2015-16 and 2016-17

3.1.2 Fruit Damage

Data revealed that damage on fruits was lesser compared to that in leaves both the years and both the seasons. It was 9.56% in the first week of April and by mid April it rose to 51.44%. After a brief dip in May first fortnight from 46.45%, it climbed back to 56.25% by May end. (Fig.3). In the second year of study, damaged ranged from 4.21% in the second week of March to the a maximum of 10.92% in the fourth week of May, though there was a little decrease in the second week of May. Up to 3.5% of tomato fruits were damaged by this pest in studies in Karnataka [5]. 50% infestation on fruit was reported by *T. absoluta* on tomato in *rabi* season in Chittoor dt of Andhra Pradesh [18].

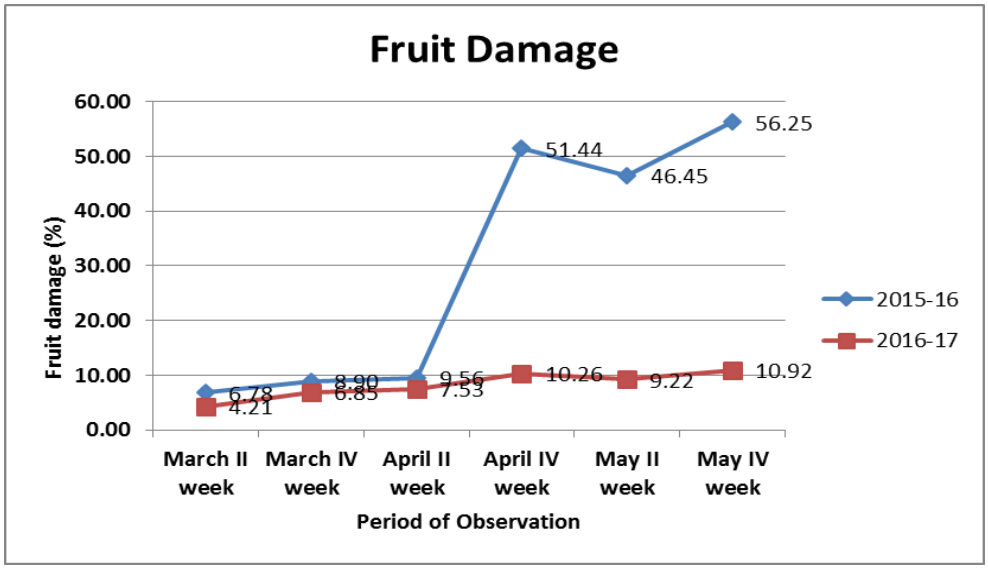

Fig 3: Fruit damage caused by *T. absoluta* in tomato in *rabi* 2015-16 and 2016-17

3.2 Roving Surveys in farmers' fields of Shamshabad and Moinabad districts to know the seasonal incidence

Results of surveys in *kharif* 2015 revealed that the pest caused mines on leaves from 30 SWk to 37 SWk. Maximum no.of leaf mines were recorded in Amdapur village (1.8 mines/plant) followed by Surangal (1.6 mines/plant) and Bakaram (1.3 mines/plant). In the 30th SWk, Surangal recorded 7 mines/plant and maximum mines per week were recorded in Amdapur (0.9/plant) in 32nd SWk. More mines were observed from 31 SWk to 33 SWk in all the locations observed. Least no.of mines (0.2) were recorded in Sayyaidguda over a span of ten weeks. Sriramnagar, Bahadurguda, Peddagolconda and Aziznagar registered populations between 0.3 and 1.2 mines/plant (Table.1). During *rabi* 2015-16, incidence of leaf mines was lesser compared to *kharif* season. It was maximum (1.60 mines/plant) in Bakaram village followed by Sriramnagar (1.45 mines/plant) and 1.27 mines/plant in Venkatapur village. In the rest of the villages surveyed, incidence ranged from 0.36 to 1.18 mines/plant (Table. 2.). Explorative surveys revealed the presence of *T. absoluta* in all the 10 villages of Bengaluru Rural and Bengaluru Urban districts and reported the intensity of damage to be as low as 0.08 mines/plant at Thirumalapura and Gudadhalli to the highest of 14.08 mines/plant Ivarakandapura. The intensity was severe in Shivakote and Ivarakandapura villages recording up to 9 and 14 mines per plant, respectively. Peak damage of 30-40 total mines/plant were recorded in these villages [5]. This intensity was much higher than what was found in our areas.

Table 1: Seasonal incidence of *T. absoluta* (live mines /5 leaves/plant) in Shamshabad and Moinabad Mandals of Rangareddy district, Telangana State in *kharif*, 2015

Villages	No.of live mines/5 leaves/plant across Standard Meteorological Weeks										
	28	29	30	31	32	33	34	35	36	37	Mean
Sayyaidguda	0	0	0	1	0	1	0	0	0	0	0.20
Sriramnagar-2	0	0	0	1	2	0	0	0	0	0	0.30
Sriramnagar-1	0	0	0	0	2	5	0	5	0	0	1.20
Bahadurguda	0	0	0	0	1	1	0	2	0	0	0.40
Peddagolconda	0	0	0	2	0	2	0	1	0	2	0.70
Surangal	0	0	7	1	0	7	1	0	0	0	1.60
Bakaram	0	0	0	5	7	0	1	0	0	0	1.30
Amdapur	0	0	2	5	9	0	2	0	0	0	1.80
Aziznagar	0	0	0	2	2	0	0	0	0	0	0.40

Table 2: Seasonal incidence of *T. absoluta* (live mines/5 leaves/plant) in Shamshabad and Moinabad Mandals of Rangareddy district in *rabi* 2015-16.

Villages	No. of live mines/5 leaves/plant across Standard Meteorological Weeks											
	45	46	47	48	49	50	51	52	1	2	3	Mean n
Sayyaidguda	0	0	0	0	0	2	2	0	0	0	0	0.36
Kishanguda	0	0	0	0	0	0	0	2	0	2	0	0.36
Laxmi thanda	0	0	0	0	0	0	2	2	2	0	0	0.55
Bahadurguda-1	2	0	0	0	0	0	0	2	2	0	0	0.55
Bahadurguda-2	0	0	0	0	0	0	0	7	0	0	0	0.64
Aziznagar	0	0	0	0	0	0	0	0	5	0	0	0.45
Bakaram	0	2	0	1	0	1	0	2	0	1	9	1.60
Amdapur	5	5	0	0	0	2	0	0	0	1	0	1.18
Sriramnagar	0	1	2	1	0	0	0	0	9	0	3	1.45
Venkatapur	0	0	3	0	0	2	0	3	0	3	3	1.27
VRS, Rajendranagar	0	0	0	0	0	0	0	0	0	0	0	0.00

3.3 Trap catches of *T. absoluta* in farmers' fields of Shamshabad and Moinabad mandals

Study of the trap catch data revealed that maximum mean trap catches were recorded between 28 and 37 SWk. Higher trap catches were registered in Amdapur village (19.4/trap) followed by Surangal (18.6/trap/) and Sriramnagar (13.9/trap). Least catches were recorded in Sayyaidguda (4.5/trap) in a span of 10 weeks. Sriramnagar, Bhadurguda, Peddagolconda and Aziznagar witnessed catches between 5.1 and 13.1/trap (Table.3). In *kharif* 2016, ten villages of Shamshabad and Moinabad mandal were surveyed to know the incidence levels of the pest and the pest was first noticed in the 33rd standard week with no infestation in the preceeding weeks. Mean infestation levels were highest in Peddagolconda (13.22/trap), followed by 8.78 and 6.78 in Venkatapur and respectively. Least affected were Sriramnagar (4.00/trap) and Kasimbowli (3.89/trap) (Table.4).

Table 3: Trap catches of *T. absoluta* in Shamshabad and Moinabad Mandals of Rangareddy district, Telangana State *Kharif* 2015

Villages	No. of insects/trap across Standard Meteorological Weeks										
	28	29	30	31	32	33	34	35	36	37	Mean
Sayyaidguda	0	0	4	15	0	17	0	2	7	0	4.5
Sriramnagar-2	0	0	0	10	35	0	6	8	0	0	5.9
Sriramnagar-1	0	0	0	0	25	60	0	50	0	4	13.9
Bahadurguda	0	0	0	0	18	16	0	39	0	0	7.3
Peddagolconda	0	0	0	29	0	36	0	15	0	25	10.5
Surangal	2	6	60	15	0	85	18	0	0	0	18.6
Bakaram	0	1	0	45	70	0	15	0	0	0	13.1
Amdapur	0	0	30	45	80	0	35	4	0	0	19.4
Aziznagar	0	0	0	23	28	0	0	0	0	0	5.1
VRS, Rajendranagar	0	0	0	15	14	2	2	9	8	2	5.2

Table 4: Trap catches in villages of Shamshabad & Moinabad Mandals of Rangareddy district, Telangana State, *Kharif* 2016.

Village	No. of insects/trap across Standard Meteorological Weeks									
	28	29	30	31	32	33	34	35	36	Mean
Peddagolconda	0	0	0	0	0	15	100	0	4	13.22
Thondupalli	0	0	0	0	0	14	40	0	4	6.44
Bahadurguda-2	0	0	0	0	0	20	10	0	10	4.44
Bahadurguda-1	0	0	0	0	0	24	15	0	4	4.78
Laxmithanda	0	0	0	0	0	19	12	0	5	4.00
Venkatapur	0	0	0	0	0	14	30	0	35	8.78
Sriramnagar	0	0	0	0	0	0	20	0	16	4.00
Kasimbowli	0	0	0	0	0	11	15	0	9	3.89
Aziznagar	0	0	0	0	0	16	15	0	10	4.56
Amdapur	0	0	0	0	0	11	50	0	0	6.78
VRS, Rajendranagar	0	0	0	0	0	11	24	14	5	6.0 0

Study of the trap catch data revealed that in general *rabi* catches were higher compared to *kharif* catches. Maximum mean catch was recorded in Bakaram village of Shamshabad mandal (29.82/trap), followed by 22.36/trap in Sriramnagar and Venkatapur (21.36/trap). In other villages surveyed, catch ranged between 5.00/trap (Sayyaidguda) to 18.82/trap in Amdapur (Table.5). In *Rabi* 2016-17, ten villages of Shamshabad and Moinabad mandal were surveyed to know the incidence levels of the pest through the trap catches and it was understood that trap catches were highest in Bahadurguda-1 (14.38/trap), followed by 14.31/trap in Surangal followed by Peddagolconda (12.62/trap) (Table.6.).

Up to 65 males/day/trap were recorded in the pheromone traps installed for monitoring indicating the widespread prevalence of the pest in tomato fields in Karnataka, while in our study the maximum trap catch was 29.82/trap/week [5]. Till 2015-16, no larval incidence, fruit and foliar damage and male adult catches of *T. absoluta* were noticed in any of the tomato fields surveyed in Punjab. However, during 2016 *Kharif* season, few *T. absoluta* adults (1-2/trap/week) were observed in the months of September-October at two farmers fields in the villages Kartarpur and Bossar Khurd in the Patiala district [19].

Table 5: Trap catches of *T. absoluta* in Shamshabad and Moinabad Mandals of Rangareddy district, *Rabi* 2015-16.

Village	No. of insects/trap across Standard Meteorological Weeks											
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**1**	**2**	**3**	**Mean**
Sayyaidguda	8	0	4	3	0	20	20	0	0	0	0	5.00
Kishanguda	0	9	11	0	0	0	6	21	5	21	0	6.64
Laxmithanda	0	10	14	5	0	11	19	29	29	0	0	10.64
Bahadurguda-1	26	4	14	11	0	16	11	31	31	0	0	13.09
Bahadurguda-2	6	0	6	0	0	11	9	72	10	18	0	12.00
Aziznagar	18	15	6	5	0	19	19	21	55	19	0	16.09
Bakaram	150	35	10	25	0	26	6	40	5	22	9	29.82
Amdapur	60	50	7	14	0	35	8	11	0	22	0	18.82
Sriramnagar	0	26	40	30	9	0	0	15	91	0	35	22.36
Venkatapur	15	15	40	9	0	30	19	39	9	29	30	21.36
VRS,Rajendranagar	0	0	0	0	11	14	16	14	0	0	0	5.00

Table 6: Trap catches in Shamshabad and Moinabad Mandals of Rangareddy district, *Rabi* 2016-17

Villages	No. of insects/trap across Standard Meteorological Weeks													
	45	46	47	48	49	50	51	52	1	2	3	4	5	Mean
Pedda Golconda	28	40	21	25	15	8	0	0	5	0	16	6	0	12.62
Laxmi thanda	0	90	6	10	16	26	4	2	6	0	0	0	0	12.31
Bahadurguda-2	0	50	15	40	10	32	4	5	10	6	2	0	0	13.38
Bahadurguda-1	15	60	18	50	8	27	2	5	2	0	0	0	0	14.38
Sriramnagar	14	14	30	10	8	18	2	8	3	13	10	11	0	10.85
Surangal	35	35	50	20	10	10	0	0	0	15	11	0	0	14.31
Aziznagar	0	11	50	22	10	18	7	0	0	16	0	0	0	10.31
Bakaram	0	8	40	35	8	5	6	0	0	0	0	0	0	7.85
Venkatapur-2	00	0	0	10	20	20	18	20	10	9	15	15	0	10.54
Venkatapur1	11	0	45	15	9	8	5	2	0	0	0	0	0	7.31
VRS,Rajendranagar	0	0	0	0	0	0	11	4	6	4	40	15	5	6.54

3.4 Roving survey in six districts of the state

Results of this survey are presented in table no.7. with a mention of the names of the villages surveyed and it was revealed that maximum mean incidence levels were recorded in Adilabad district (73.05%), followed by Mahboobnagar district (71.3%). Incidence levels were 28.9% in Rangareddy district, 11.4% in Medak dt, 10.35% in Nalgonda dt followed by 7.3% in Warangal district, which was the least affected by *T. absoluta*. (Table.7.). Surveys were conducted by throughout greenhouses with tomato production around village Stajkovce of Serbia in late June 2011 revealed severe outbreak of *T. absoluta* in 5 inspected tomato crops locations [20]. They pest was reported to be severe in major vegetable growing areas of Serbia.

Table 7: Roving surveys in six districts of the state

S. No.	Name of the district	Village	Incidence (%)
1	Medak	Kohir	9.3
		Sangareddy	11.5
		Narsapur	13.5
		Mean	11.4
2	Rangareddy	Palgutta	25.6
		Chevella	32.5
		Alure	28.6
		Mean	28.9
3	Mahboobnagar	Jilledidhan	65.8
		Ramapuram	72.7
		Vaddepalli	75.5
		Mean	71.3
4	Adilabad	Indravelli	80.6
		Ichoda	65.5
		Mean	73.05
5	Warangal	Narsampet	5.6
		Kommala	7.4
		sangem	8.8
		Mean	7.3
6	Nalgonda	Eragandlapalli	12.5
		Thirugandlapalli	14.8
		Haliya	5.6
		Maal	8.5
		Mean	10.35

3.5 Impact of weather on leaf damage by *T. absoluta* in *Rabi*

Leaf damage and fruit damage caused by pinworm was positively correlated with maximum and minimum temperature, evening relative humidity, rainfall, rainy days, sunshine hours, wind speed, evaporation and mean temperature. The pest was found to have negatively correlation with morning relative humidity, which was in conformation with similar studies carried out on the pest in Raipur [21]. This could be the reason why the pest numbers were more in late *rabi* than in *kharif.*

Table 8: Correlation of leaf and fruit damage with weather parameters in *rabi*.

Weather parameter	Correlation value (Leaf damage)	Correlation value (Fruit damage)
Maximum Temperature	0.6879	0.7248
Minimum Temperature	0.7796	0.7704
RH I	-0.6344	-0.6395
RH II	0.0976	0.0854
Rainfall	0.08056	0.2201
Rainy days	0.0834	0.1874
Sunshine hours	0.4940	0.5412
Wind speed	0.0061	0.0282
Evaporation	0.7830	0.7982
Mean Temperature	0.8094	0.8228

Multiple linear regression studies were conducted for leaf damage in *kharif* and leaf damage and fruit damage with respective weather parameters but leaf and fruit damage by tomato pin worm was not influenced by the weather parameter either in *kharif* nor in *rabi*.

T. absoluta has been causing huge losses to tomato farmers in recent years. Incidence in *rabi* is higher than in *kharif*. In India, its incidence has been noticed mainly on tomato. But chances are there that it migrates to other solanaceous crops. Telangana state has high acreage of tomato and so regular surveillance of this devastating invasive pest is the need of the hour. Natural control of the pest by predators spiders, coccinellids and other Hemipterans has been reported [22]. There is also an urgent need for domestic quarantine measures to curtail the pest from spreading further to other tomato growing regions of India [5]. *T. absoluta* is multivoltine and according to rapid population growth should be treated as r-selected species [9] and can overwinter in egg or pupa or adult stages [5] make it a difficult-to-manage one. Despite the diverse pest complex on tomato [23], their major natural enemies' assemblage is largely constituted by few predatory omnivorous mirid species. Mirids are polyphagous, feeding on almost the entire spectrum of tomato pests. These mirid predators show phytophagous habits that support their development or reproduction to a variable rate depending on the plant substrate [24, 25]. Reports suggest that *Trichogramma pretiosum* and *Trichogrammatoidea bactrae* parasitized 51.1 and 68.2% of the eggs of *T. absoluta* with adult emergence of 97.5% and 90% respectively [26]. One more alarming factor is that it has also been reported from plants of Fabaceae family like *Phaseolus vulgaris, Vicia faba, Vigna unguiculata* [27] and *Medicago sativa* [28], which are commonly cultivated plants in Nepal. Hence, this pest can spread even into new locations where tomato is not cultivated and even in absence of solanaceous vegetables

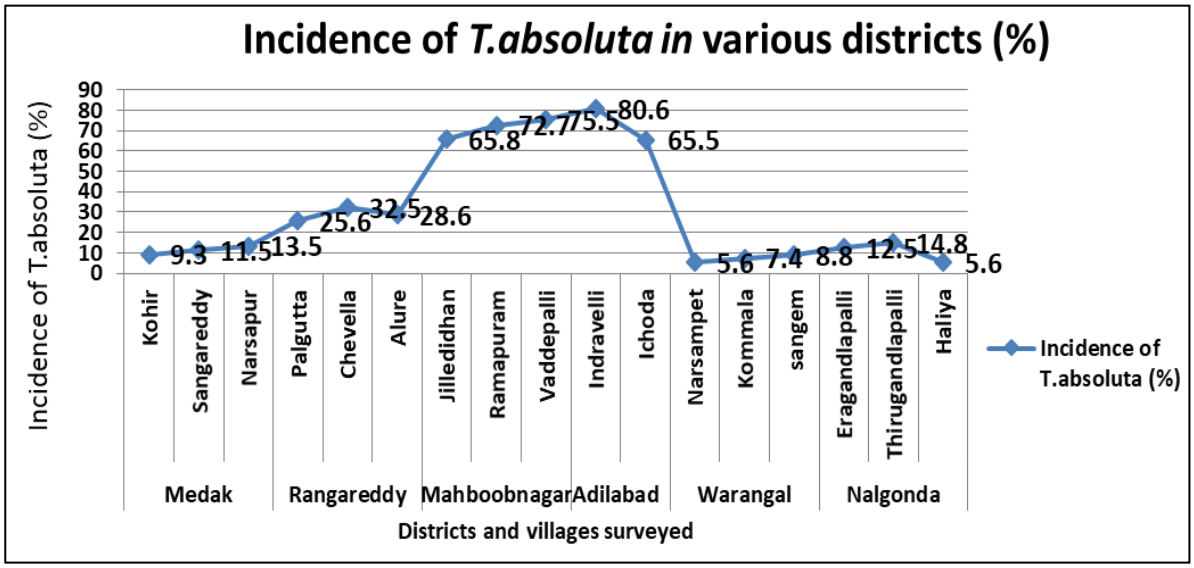

Fig 4: Incidence (%) of *T. absoluta* in different districts of Telangana State

4. Conclusion

Our work focussed on the level of incidence of the pinworm in Telangana districts and it was found that damage was less in *kharif* compared to *rabi* with the pest peaking once in mid March and again in May. Also leaf damage rose to a maximum of 90.13% and was more than fruit damage (maximum 56.25%) at the vegetable research station, Rajendranagar both the years. This was probably because peak infestation levels could have coincided with the vegetative stage of the crop. Study on the incidence levels in villages of Shamshabad and Moinabad mandals of Rangareddy dt. revelaed that *T. absoluta* caused leaf mines in all the fields of the villages considered for observation though the degree of incidence varied among the villages. Between 2014 and 2016, the pest spread greatly in different parts of the country and this calls for further studies on the host range and food preferences of the pest. Sex pheromone-based strategies (*i.e.* mass trapping and mating disruption) are promising techniques to control this invading pest [29]. Intensive studies aimed at understanding alternative methods of management *viz*., biological and biorational methods need to be understood to prevent the pest from causing huge economic losses to tomato farmers.

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