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TOMATO LEAF MINER, *TUTA ABSOLUTA* (LEP., GELECHIIDAE), POPULATION FLUCTUATION AND SEASONAL ACTIVITY IN THE FIELD

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Abstract:
Seasonal activity and population fluctuation of tomato leaf miner, Tuta absoluta (Meyrick), a dangerous pest of tomato fields in Tehran province, were determined in Varamin region, south of Tehran province in 2015-2016. Number of moths in pheromone trap and number of larvae per plant were counted weekly in a trail tomato field. The trap capture began on mid-April in warm dry spring of 2015 and on mid-May in cool wet spring of 2016. The first and highest moth peaks in trap occurred about one month earlier in 2015 than 2016. The larval density per plant at the highest peak reached 2.34 and 10.8 in 2015 and 2016, respectively. A temperature range of 25-30°C was desirable to the pest in which the interval of successive peaks decreased. In both years, the pest created three generations over a growing season, according to larval peaks, but 11 over a year, according to trap data, that the 11th generation overwintered. The temperature of 35°C and above limited larval activity and decreased the population. After the crop removed, the pest population declined due to host shortage, but it increased with the access of hosts in the second cultivation since mid-September until the cold season.

Keywords: Tomato Pests; Population Change; Generation; Degree Day; Pheromone Trap.

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1. Introduction

Tomato is an important crop in Iran that was consumed as fresh or processed type. The tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera, Gelechiidae) is a devastating pest with tomato preference which attacks all parts of the plant, but it feeds on other solanaceous plants such as aubergine (*Solanum melongena* L.), potato (*Solanum tuberosum* L.), pepper (*Capsicum annuum* L.), tobacco (*Nicotiana tabacum* L.), cape gooseberry (*Physalis peruviana* L.) as well as on non-cultivated Solanaceae (*Solanum nigrum* L., *Solanum elaeagnifolium* Cavanilles) and other weeds, jimson weed, *Datura stramonium* L. and common bean (*Phaseolus vulgaris L.*) (Garica & Espul, 1982, Pereyra and Sanches, 2006, Desneux *et al.*, 2010). The alternative host plants allow *T. absoluta* to survive in many habitats in the absence of tomato crops and without control it causes yield losses up to 100% (Tropea *et al.*, 2012, Estay, 2000).

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The tomato leaf miner has a wide range of dispersion. The pest is native to South America, but has spread to Europe, North Africa and some Asian countries and has recently been reported from Kuwait and Bahrain (Brévault *et al*., 2014, Pfeiffer *et al*., 2013, Chermiti *et al*., 2009). The pest was reported for the first time in Iran from West Azerbaijan in 2010 and then from other provinces including Tehran in 2011 (Baniameri and Cheraghian, 2012, Javadi Emamzadeh and Cheraghian 2013). The pest limited the cultivation of tomatoes in Tehran province in 2012-2013, but its population was gradually controlled in subsequent years. Population fluctuation of the pest has been studied in Iran for the first time in Lorestan province using pheromone delta trap in 2013-2014 (Bahirai *et al.*, 2015). They found the peak of trapped population on early August and 6-7 generations per year on the basis of physiological time and pheromone trap data. Hagshenas (2016) reported 4-5 generations for the pest in plant-growth season using pheromone traps and establishing cages on field in Isfahan province, Iran. In Egypt, Tabikha and Hassan (2015) detected 11 generations per year using pheromone traps; but in Chile, it had been reported 7-8 generations per year by Vargas (1970).

T. absoluta is a multivoltine species, which rapidly develops in favorable environmental conditions, with overlapping life cycles (Guenaoui *et al*., 2010). It has a high reproductive potential and a female can lay 230-260 eggs in desirable condition (Barrientos *et al.*, 1998). Investigating population fluctuations of the pest during growth season which was studied in the project in 2015-2016, can be important in its forecasting and integrated control.

2. Materials and Methods

Population Fluctuation Determined by Trap

Population fluctuation of *T. absoluta* was determined at a tomato field in research station of Tehran Agricultural and Natural Resources Research and Education Center in Varamin, in two subsequent years, 2015-2016. Tomatoes transplanted in the field at early May in both years and simultaneously a sticky pheromone delta trap (green delta trap with white sticky board 19 × 20 cm) was established near the field at height of 1 m. The trap was loaded with a sex pheromone capsule (Russell IPM production) that being exchanged every 5-6 weeks. Number of captured males in trap was counted twice a week and their sum was recorded weekly. The sticky board was replaced when its surface had been filled by moths or dusts. The weekly recording of trapped moths continued after crop removing to late November when the cold weather curbed the pest activity.

Annual Generations Determined by Thermal Constant and Degree Day

On the basis of Meteorological data of the region, annual number of generations of *T. absoluta* was determined through daily degree units using two methods as follows (Murray 2008):

1) Average Daily Temperature

Daily Degree Units (DDU) = [(Daily Maximum Temperature + Daily Minimum Temperature)/2] –Lower temperature threshold (T_0).

2) Modified Average Daily Temperature

When the daily minimum temperature is lower than the baseline (lower temperature threshold), or the daily maximum temperature is higher than the cutoff (upper temperature threshold), the formula needs to be modified as:

The lower temperature threshold (T_0) is used instead of the daily minimum temperature or the upper temperature threshold (T_{max}) is used instead of the daily maximum temperature. Therefore, the number of generations could be determined as (Jasic 1975):
Number of Generations = Σ DDU / Thermal Constant (C)

T_0 and T_{max} for *T. absoluta*'s developing from egg to adult were 8°C (Barrientos *et al.* 1998, Desneux *et al.* 2010) and 37.3°C (Krechemer and Foerster 2015) respectively. Thermal constant required for egg-to-adult developments of *T. absoluta* in the calculation method of 1 and 2 were 450 (Abolmaaty *et al.* 2010) and 416.7 (Krechemer and Foerster 2015) degree day (DD) units, respectively.

The first peak of moths in the pheromone trap was considered as a biofix (starting point for accumulating degree days) (Murray 2008, Bahirai *et al.* 2015).

By the trap we measured the adult peak interval between a generation and the subsequent one, but the metioned thermal constants, 450 or 416.7 (DD), are the amounts of heat for developing from egg to adult, and therefore a time was needed for females of a generation to produce peak of eggs which will lead the peak of emerging adults in the next generation. The pre-oviposition period of the pest on different tomato cultivars is 0.47-2.4 days (Silva *et al*. 2015, Ghaderi 2017a) and it needs 3-4 days to reach the peak of oviposition (Ghaderi 2017a); therefore, it takes 3.5-6.5 days from adults' emergence to reach the peak of oviposition.

Larval Population Fluctuation on Plants

After transplantation, the weekly observation of the plants in the tomato field continued until the observation of the larval mine, and then the live larvae per plant were recorded on a weekly basis. For this purpose, more than 200 plants were sampled and the number of live larvae or mines containing alive larva counted in all parts of the plant (leaves, stems and end buds), which were observed almost all of them on the leaves. Sampling continued until plants drying.

3. Results and Discussions

The climate has direct influence on insect population changes, therefore the pest population changes assessed in warm-dry and cool-wet springs in 2015 and 2016, respectively. All of the pest biological events delayed about one month in 2016 compared with 2015.

Population Changes in Pheromone Trap

In the Year of 2015

Tomatoes were transplanted and the pheromone traps were established simultaneously at the central research station in early May in both years of 2015 and 2016. Adults of the pest were seen in the trap at high population in 2015 and thereafter the females laid eggs on transplants so that the first peak of adults in trap and larval population on plants were seen on May17, 2015 and May19, 2015, respectively (Fig. 1). It means that the adult peak of hibernated generation had been made before May and the first observed peak in Fig. 1 relates to adults of the first generation. After 3 weeks, the second generation adults' peak occurred in the trap but the young larvae of the third generation could not survive at the heat of more than average of 30°C in late June and died as eggs or first instar larvae into their short mines. Therefore, the third generation population peak was

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shorter than the second one. The tomato plants went down and drought since early July and removed after Mid-July. While the larval population declined, the adult population of the fourth generation reached the highest peak in the trap, which means that these adults could not be from our trial field but are transferred from other fields or greenhouses of the area into the trap. After the host plants removed from the area, the pest starved and the population severely declined. With access to the hosts at second cultivations in the area the pest began to repair the population from Mid-September and increased over 4 generations until cold season.

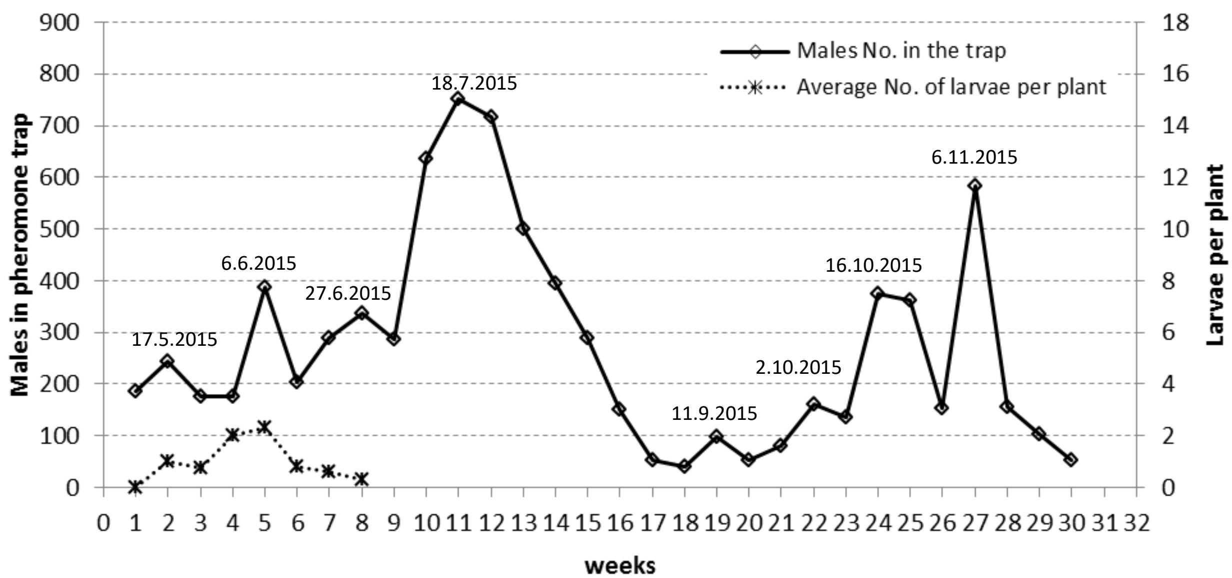

Figure 1: Population fluctuation of male pests in pheromone trap and larvae on plants in 2015 (May.3.2015-November.28.2015)

Therefore, on the basis of trap data, the pest produced 11 generations in the year 2015 which the 11th generation went to hibernation. When average temperature decreased below 30°C since late August and reached to 25°C in October, the intervals of flight peaks reduced to two weeks, which seems that the temperature about 25-30°C is favorable to the pest (Figure 2).

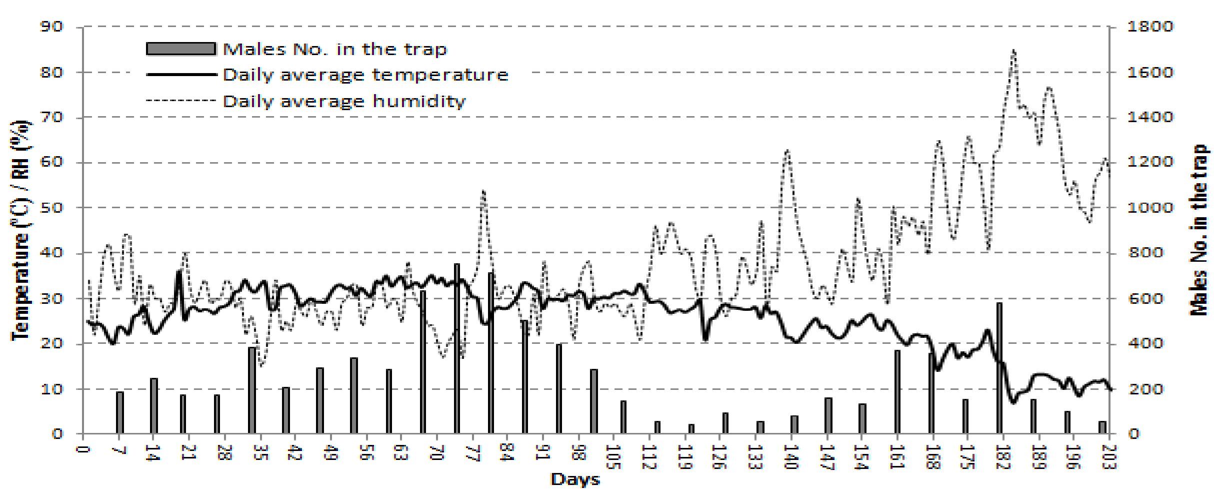

Figure 2: Population changes of males in pheromone trap along changes of temperature and humidity in 2015 (May.3.2015-November.28.2015)

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In the year of 2016

The moths got trapped in low population in early May and the first adult peak was seen on May.28.2016 but the first larvae on plants on June.18.2106 (Fig. 3). It shows that the first peak relates to hibernated individuals which occurred about one month later than 2016 related to cool and rainy climate (Fig. 4). In favorable temperatures, below the average of 30°C, the pest developed quickly in the two first generations and observed intervals between the moth peaks in trap reduced to two weeks. This state repeated frequently in 2016 and even though biological events started one month later than 2015, the number of generations was equal in the two years.

The tomato plants went down and drought since early August and removed after Mid-August. For the cooler climate and prolonged plant growth season in 2016, the second cultivation of the pest hosts occurred no longer after crop harvest in the area and therefore the pest did not experience starvation for a long time and created the next generations without severe population decrease.

Like the past year, the pest produced 11 generations in the year 2016 which the 11th generation went to hibernation. Therefore, more generations of the pest were seen in Varamin as a warm temperate region, while 6 and 7 generations per year reported form Boroujerd County, Lorestan Province of Iran as cold temperate region in 2013 and 2014 (Bahirai *et al.* 2015).

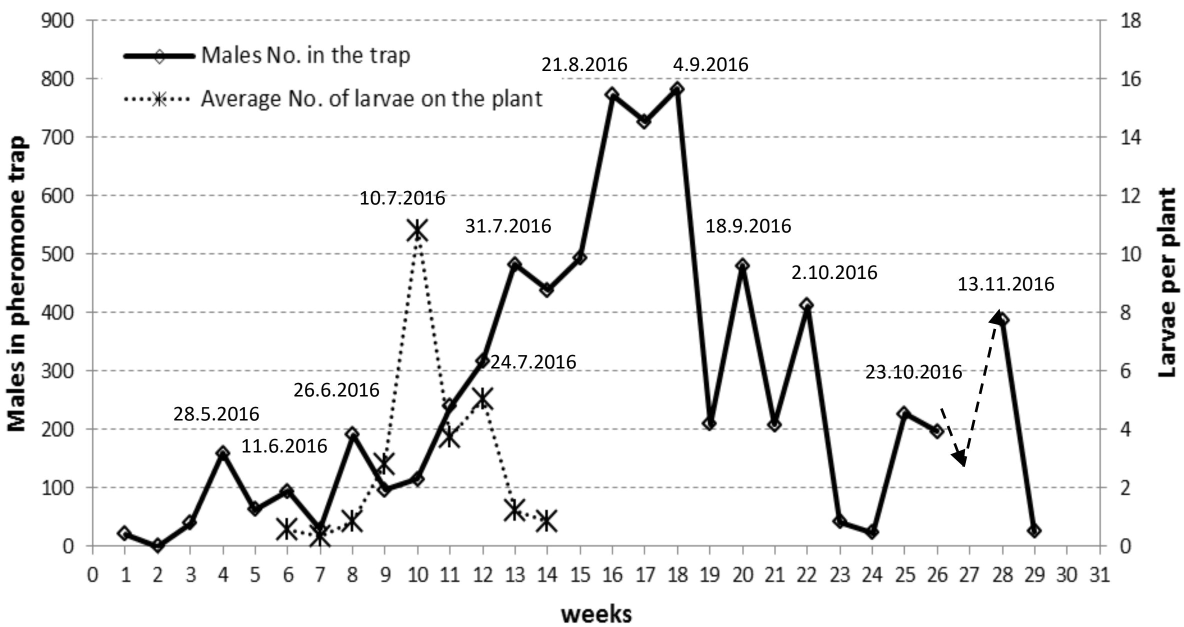

Figure 3: Population fluctuation of males of the pest in pheromone trap and larvae on plants in 2016 (April.30.2016-November.21.2016)

* Note: Data of the week 27th has been estimated due to destruction of the pheromone trap.

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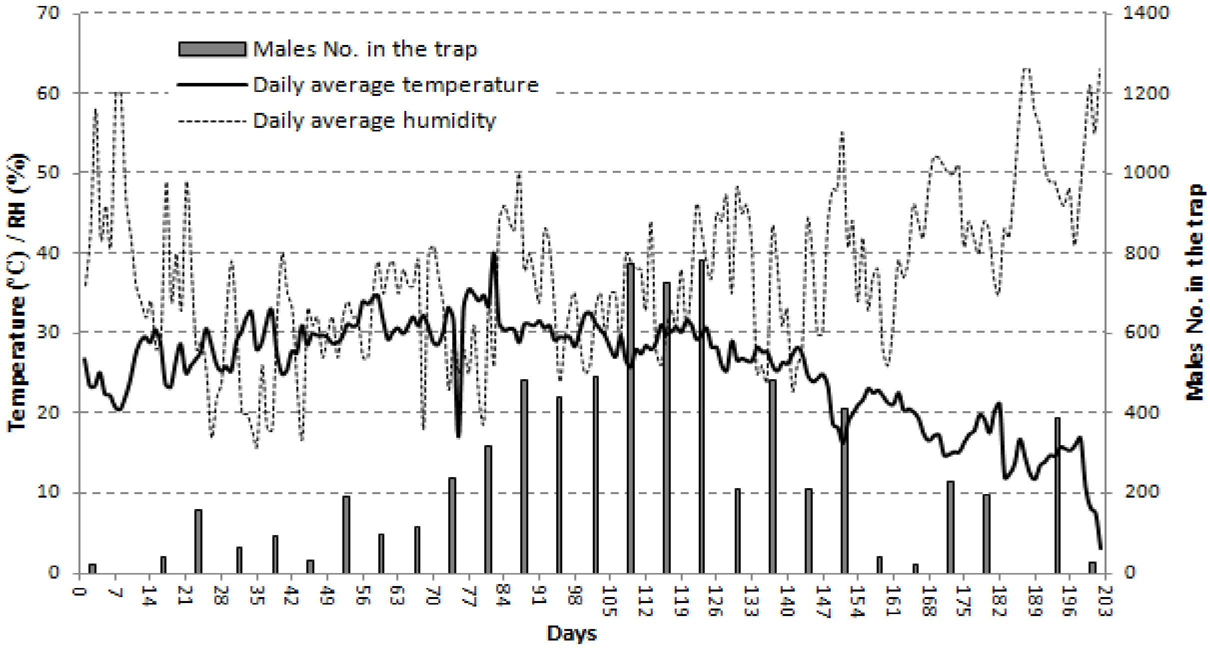

Figure 4: Population changes of males in pheromone trap along changes of temperature and humidity in 2016 (April.30.2016-November.21.2016)

Annual Generations Estimated by Thermal Constant and Degree Day

The first peak of males in the pheromone trap considered as biofix. For good matching of observed and expected peak dates, a 6-day and 4-day interval in 2015 and a 2-day and 0-day interval in 2016 considered as needed time from adults emergence peak to laid eggs peak in the methods of Average Daily Temperature and Modified Average Daily Temperature respectively. Good matches were seen between the observed and expected peak dates until September 2015 (Table 1) but after that the observed generation time became shorter in the cooler condition from the first week of September 2015. This condition observed frequently in the next year when the temperatures came below 30°C (Table 2).

After cultivation is removed the pest population decreased due to starvation and could not show the two expected population peaks since mid-July to early September; but the population started to increase after access to hosts in the second cultivations common in the area. Therefore, the pest created 10 expected but 11 observed generations in both years that the 11th generation went to hibernation.

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Table 1: Comparing the observed and expected population peak dates of *Tuta absoluta* in 2015

Week (start at May.3.2015)	**Average temperature** (°C)	**Observed**		**Expected**		
		Generation	peak of males in pheromone trap	Generation	peaks based on: **Modified Average Daily Temperature Method,** 417 DD thermal constant, (4 day interval from adult emergence to egg laying peaks)	peaks based on: **Average Daily Temperature Method,** 450 DD thermal constant, (6 days interval from adult emergence to egg laying peaks)
1	22.6	1		1		
2	24.9		May.17		Biofix: May.17.2015	Biofix: May.17.2015
3	26.8	2		2		
4	27.9					
5	32		June.6		June.5	June.6
6	31.4	3		3		
7	29.7					
8	32.3		June.27		June.27	June.26
9	33.6	4		4		
10	33.6					
11	33.2		July.18		July.18	July.14
12	27.3	5		5		
13	31.3					
14	30.5				August.7	August.3
15	30.3	6		6		
16	31.8					
17	28.5				August.29	August.23
18	27.2	7		7		
19	28.2		September.11			
20	26.2	8			September.16	September.13
21	23			8		
22	23.1		October.2			
23	25	9			October.7	October.7
24	21.5		October.16	9		
25	17.7	10				
26	19.1					
27	10.6		November.6		November.5	November.9

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Table 2: Comparing the observed and expected population peak dates of *Tuta absoluta* in 2016

Week (start at April.30.2016)	**Average temperature** (°C)	**Observed**		**Expected**		
		Generation	peak of males in pheromone trap	Generation	peaks based on: **Modified Average Daily Temperature Method** 417 DD thermal constant (0 day interval from adult emergence to egg laying peaks)	peaks based on: **Average Daily Temperature Method** 450 DD thermal constant (2 days interval from adult emergence to egg laying peaks)
1	23.9	Hibernated		Hibernated		
2	22.4					
3	28.1					
4	26.2		May.28		Biofix: May.28.2016	Biofix: May.28.2016
5	27.6	1		1		
6	30.4		June.11		June.12	June.14
7	27.8	2		2		
8	29.6		June.26		June.28	June.30
9	32.4	3		3		
10	30.7					
11	30.8				July.16	July.15
12	34	4		4		
13	30.8		July.31		August.2	July.30
14	30.5	5		5		
15	30.5					August.15
16	28.1		August.21		August.19	
17	28.8	6		6		
18	30.4		September.4		September.5	September.1
19	27.7	7		7		
20	27		September.18		September.20	September.18
21	26.4	8		8		
22	21.3		October.2			
23	21.4	9			October.7	October.9
24	21.1			9		
25	16.7		October.23			
26	17.2	10			October.30	November.4
27	16.2			10		
28	13.6		November.13			

Larval Population Changes of the Pest in Tomato Growing Season

In the year of 2015

The larvae were seen on tomato plants for the first time on May.19.2015 and population increased until June 9 then decreased toward the end of season (Fig. 5). Two larval population peaks were seen with two weeks interval that the second was higher and occurred on June 9. Therefore, the interval from early to mid-June was the most abundant period of larvae in 2015 that was below the

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economic threshold, 4.15-5.04 larvae per plant on different tomato cultivars in field condition (Ghaderi *et al.* 2017b). After that with increasing temperature, average of 30-32°C, most of laid eggs in the third generation were not hatched or the young larvae from hatched eggs died in early stages into the short larval mines so that very low population of larvae leaved towards the end of season. The cultivation removed with plant drying and decaying on Mid-July.

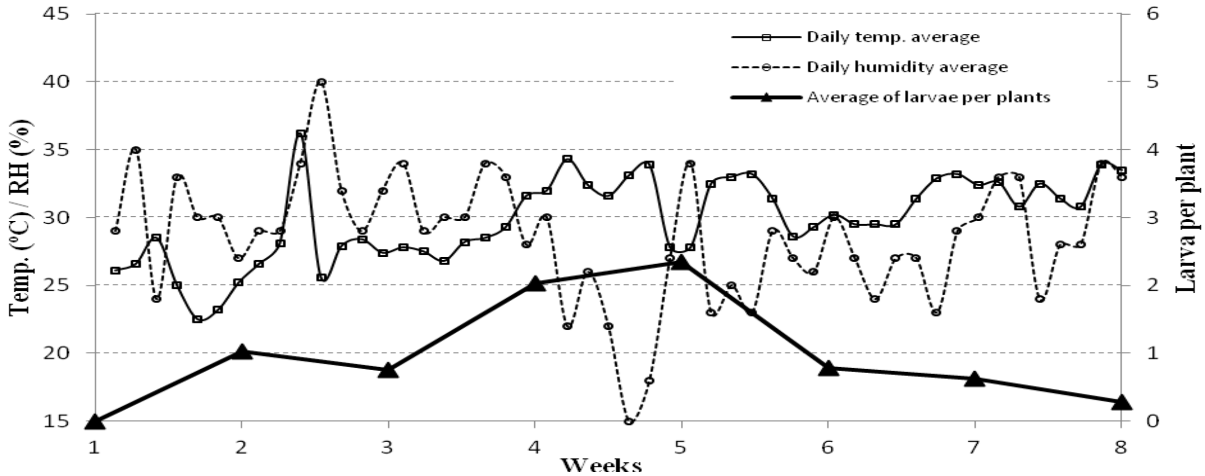

Figure 5: Larval population changes on plant along changes of temperature and humidity in 2015 (May.12.2015-June.30.2015)

In the year of 2016

The larvae were seen on tomato plants for the first time on June.12.2016 and population increased until July10 then decreased toward the end of season (Fig. 6). As the year 2015, two larval population peaks were seen with two weeks interval but the first was higher and above the economic threshold, 4.15-5.04 larvae per plant that occurred on July10. The interval from early to mid July was the most destructive period in 2016. Increased temperature during the third week of July, average of 34°C, prevented the pest population increase and it fell down towards the end of July. Only a few larvae of third generation produced from pioneered individual of the second generation were seen toward the end of season. The cultivation removed with plant drying and decaying on Mid-August.

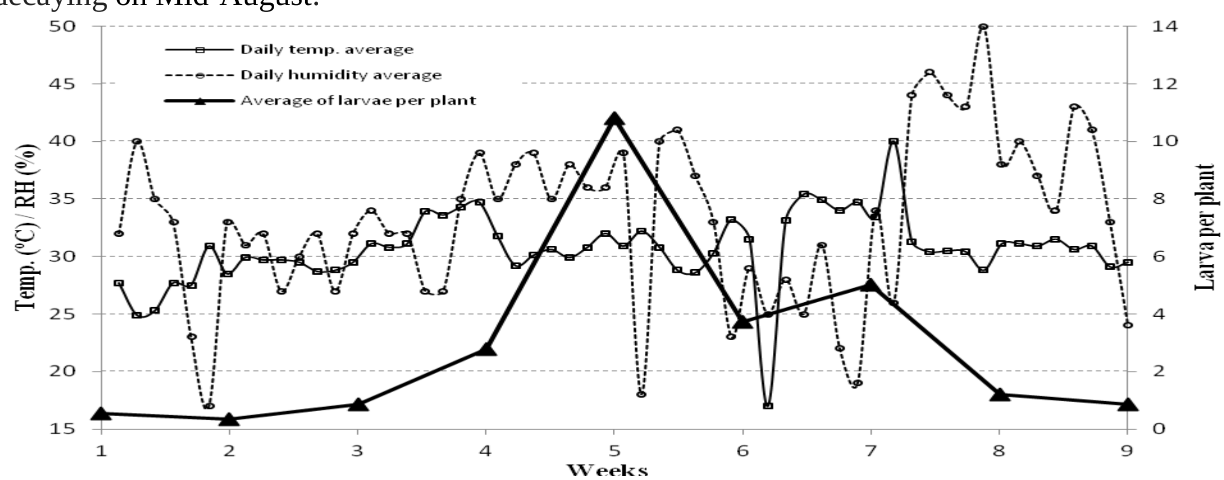

Figure 6: Larval population changes on plant along changes of temperature and humidity in 2016 (June.12.2016-August.7.2016)

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4. Conclusions and Recommendations

In hot dry and cool wet springs, the pest larvae get started to feed on plants from mid-April and mid-May respectively. Therefore, they must be started to monitor from these times to find an action threshold, about Early-June and Early-July respectively, in IPM program.

The pest had 3 generations over growing season on open field tomatoes that the last limited by high temperatures; resulted that the first two generations need to control.

The pest population declines after crop harvesting and host shortage and increases after subsequent host cultivations; therefore, it is concluded that alternative non-host cultivations can control the pest.

Pheromone trap data is not sufficient for monitoring the field infestation and plant inspection and sampling is necessary.

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