Current Science International 3(3): 252-259, 2014
ISSN: 2077-4435

Life Table Parameters and Fluctuations in the Population Density of the Moth *Tuta absoluta* (Meyrick) - (Lepidoptera: Gelechiidae)

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ABSTRACT

The biology of *Tuta absoluta* and its life parameters were studied under four controlled temperatures. Fluctuations in the population density of the moth over a period of two years 2012-2014 and during different tomato rotations have been investigated. Eight peaks of abundance occurred during the year 2012, including three peaks in early summer plantations and four peaks in nile plantations and an additional peak between the two rotations. In 2013, five peaks were recorded in the summer plantations and three peaks in winter plantations. The rate of increase in insect population reached a high index in March-April when the average temperature ranged between 16.19 and 21.13 ˚C.

Key words: *Tuta absoluta*, life parameters, population density, peaks of abundance.

Introduction

The tomato leaf miner *Tuta absoluta* (Meyrick) became a serious pest to tomato cultivations in Egypt since 2009, where it causes great damage to the crop in different governorates. The adult of *T. absoluta* is a micro lepidopteran moth which is nocturnal and may be found between the leaves of host plants during the day (Fera, 2009). The larvae attack the tomato plants in all developmental stages causing losses of up to 100% by attacking leaves, flowers, stems and especially fruits besides mining their leaves. The insect passes through four developmental stages, egg, larva, pupa and adult. This pest is widely spread in South America (Garcia, Espul, 1982, Souza *et al*. 1983, EPPO, 2005), Europe and Middle East countries (EPPO, 2009).

The present work has been designed to study the biology, life table parameters and fluctuation in population density of the moths under our local environmental conditions. The environmental conditions such as temperature and relative humidity are factors influencing insect physiology and behavior. Temperature has a direct influence on the insect activity and rate of development. This is based on the accumulation of heat measured in physiological rather than chronological time, (Varges, 1970, Zalom, Wilson, 1982). The knowledge obtained will be of great value to give scientific bases for its control.

Materials and Methods

1- Rearing of Tuta absoluta on tomato plants.

A laboratory colony of *T. absoluta* was raised with larvae collected from infested tomato cultivations in Bernucht village, Al Ayyat, Giza. Larvae were dislodged from leaves and were housed in a wooden and nylon cage. The cage bottom is lined with sandy soil and provided with tomato terminal buds and clean leaves for larvae feeding. When pupation was completed, the cocoons were carefully collected to produce the first generation. After emergence, adults were transferred to a new cage using an aspirator. The cage was about (60×50×50 cm) and provided with tomato plant pots (45 days old) for oviposition. Adults were fed with a sugar solution (15 %). The tomato pots were replaced weekly for egg laying. (Gonza´lez-Cabrera *et al*. 2011, Fargalla , Shalaby, 2013, Youssef , Hassan, 2013, Shalaby *et al*. 2013).

The plants were cultivated in pots using as substrate a mixture of soil, sand, and organic matter (compost) in the proportion of 1:1:1. This mixture was mixed with 50 gm of the fertilizer 19+19+19 (N+P+K). Each plant was fertilized every 15 days with 100 ml of a bio-cucumber solution and 10 gm of calcium nitrate diluted in 500 ml water.

2- Life table parameters of Tuta absoluta.

The duration of different developmental stages of *T. absoluta* and the life table parameters were estimated under controlled temperature conditions namely 15, 20, 25 and 30 ˚C. For this purpose, 30 newly molted pupae were placed in plastic jars (2 L) lined with sandy soil, the pupal duration and percentage of adult emergence were calculated. After adult emergence the jars were provided with tomato terminal buds and clean leaves for

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egg laying. The leaves were examined daily to determine the pre-oviposition period, the total count of eggs and the adult longevity. The deposited eggs were examined daily until hatching for calculating the incubation period of eggs. After hatching the newly hatched larvae depend on tomato leaves for feeding. The fresh leaves were introduced daily to the larvae, where the larvae were observed to move and emigrate from withered leaves to fresh leaves. The larval, pupal duration, longevity of adult were calculated. The experiment was repeated three times as replicates.

3- Seasonal variation and population density of Tuta absoluta.

T. absoluta is a nocturnal insect. The light trap was used to determine the seasonal variation and population density of this insect over a period of two years (Jan., 2012 – Jan., 2014). For this purpose, a tomato cultivated area (10 feddans) was selected in Bernucht village to carry out these investigations.

The light trap was installed 2m above the ground. This trap consists of four parts, namely (I) - Light source (105 watt). (II) - Funnel shaped lid with its orifice to the lower direction to connect with a glass jar. (III) - Collecting chamber (glass jar) containing sodium cyanide. (IV) - Lid on the top to protect from unexpected night showers. The light source was switched on daily after sunset, while disconnected during daytime because adults of *T. absoluta* are nocturnal and usually hide during the day between leaves.

The moths were collected weekly and transferred to the laboratory to be sorted. Since the number of moths collected was so large; it was found advisable to weight the whole yield of moths of *T. absoluta* using a digital balance. The total number of moths / one gm of the yield was calculated to be 505.1 ± 20.3 individuals.

The total number of moths / month was taken as the population index. The rate of increase in the population density was calculated by dividing the total population in any month over that of the previous one and the average annual fluctuation was calculated by dividing the maximum total population over the minimum one.

Records of the main environmental factors, minimum temperature, maximum temperature, mean temperature and mean % relative humidity were obtained from the Central Laboratory for Agricultural Climate (CLAC).

Results:

1- Biology and life table of T. absoluta under four controlled temperatures.

The biology and life table parameters of *T. absoluta* were studied under four controlled temperatures and the data are presented in table (1).

Egg stage:

The newly deposited eggs are oval in shape and creamy white in color then turn to yellow and finally black before hatching. The incubation period was 14.65 ± 0.9 days at 15 ˚C, then decreased to 8.7 ± 0.4, 5.61 ± 0.2 and 3.7 ± 0.16 days with increase of the temperature to 20, 25 and 30 ˚C, respectively, and the decrease was significant at all temperatures.

Larval stage:

T. absoluta passed through four larval instars. Just after hatching the larvae are creamy yellow, then they feed and become greenish in color and the dorsal region turns to reddish when they are close to pupate. Data presented in table (1) show that the larval duration was 31.98 ± 1.7 days at 15 ˚C. Increase of temperature shortened significantly the larval duration being 21.4 ± 1.1, 14.56 ± 0.2 and 9.2 ± 0.21 days at 20, 25 and 30 ˚C, respectively.

Pupal stage:

After development of 4th larval instar the insect pupates, and the pupa has a cylindrical shape, greenish in color then turns to brown. From the data in table (1), it appears that the mean pupal duration was 22.13 ± 0.53 days at 15 ˚C, as compared to 16.58 ± 1.2, 10.93 ± 0.31 and 6.48 ± 0.19 days for the pupae incubated at 20, 25 and 30 ˚C, respectively, and the difference was highly significant at all tested temperatures.

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Adult stage:

Following pupation, the moth emerges to give male and female and both sexes can be distinguished through their size where the females are wider and more voluminous than the males. The abdomen of the female is brown in color but it is creamy in male. The male longevity was 21.6 ± 0.8, 16.3 ± 0.4, 10.1 ± 0.7 and 6.7 ± 0.2 days at the four tested temperatures, respectively, and the differences are statistically significant. On the other hand, the female longevity lasted longer being 25.8 ± 1.9 at 15 ˚C and then it decreased to be 21.3± 0.9, 14.3 ± 0.2 and 11.9 ± 0.18 at the other 3 tested temperatures and the differences are statistically significant.

Pre-oviposition period:

The data presented in table (1) show that the duration of pre-oviposition period was 4.6±0.5, 4 ± 0.63, 2.9 ± 0.83 and 2.3 ± 0.65 days at the four tested temperatures, respectively.

Egg production:

Results in table (1) reveal that the highest egg production was obtained at 20 ˚C being 162 ± 30.94 eggs / female, this decreased to 159 ± 35.5 eggs / female at 15 ˚C. At higher temperatures, the mean production was 128.9 ±31.67 and 115.3 ± 23.64 eggs / female after rearing in 25 and 30 ˚C, respectively. Meanwhile, days showing highest egg deposition were tenth, seventh, fifth and fifth days after the female emergence at the four tested temperatures, respectively.

Life cycle:

Data given in table (1) indicate that the life cycle of the male is shorter than the female. So, at 15 ˚C, the duration of the male cycle was 90.63 ± 1.6 days compared to 94.56 ± 1.2 days in the female. This relation holds the same at all tested temperatures.

Table 1: Biology and life table of *T. absoluta* under four controlled temperatures.

Duration of stages		Temperature			
		15 ˚C	20 ˚C	25 ˚C	30 ˚C
Eggs	Durations / days ± SD	14.65 ± 0.9	8.7 ± 0.4	5.61 ± 0.2	3.7 ± 0.16
Larvae		31.98 ± 1.7	21.4 ± 1.1	14.56 ± 0.2	9.2 ± 0.21
Pupae		22.13 ± 0.53	16.58 ± 1.2	10.93 ± 0.31	6.48 ± 0.19
Longevity of Male		21.6 ± 0.8	16.3 ± 0.4	10.1 ± 0.7	6.7 ± 0.2
Longevity of Female		25.8 ± 1.9	21.3 ± 0.9	14.3 ± 0.2	11.9 ± 0.18
Life cycle of male		90.63 ± 1.6	62.98± 7.8	41.2± 3.7	26.08± 0.34
Life cycle of female		94.56± 1.2	67.98± 1.6	45.4± 0.61	31.28± 0.44
Pre-oviposition		4.6±0.5	4±0.63	2.9±0.83	2.3±0.65
No. of eggs/ Female		159 ± 35.5	162 ± 30.94	128.9±31.67	115.3±23.64
Day showing highest egg production		10^{th} day ± 1.4	7^{th} day ± 0.77	5^{th} day ± 1.83	5^{th} day ± 0.63

2- Seasonal variation and population density of Tuta absoluta.

Field studies were carried out to determine the seasonal variation and population density of *T. absoluta* in tomato cultivations in Bernucht, Giza governorate for two years, starting from the last week of January 2012. An area of 10 Feddans cultivated with different tomato cultivars was selected for this purpose. A light trap was installed in the field and the adult moths were collected bimonthly for two years and transferred to the laboratory to be sorted and counted.

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2-1- Seasonal variation and population fluctuation density during 2012- 2013.

The fluctuation in the population density of *T. absoluta* in the early summer and nile plantations during the year 2012 are given in table (2) and illustrated in Fig. (1). The data show that, in the early summer plantation, *T. absoluta* appears in the 1st week of February, where the number of adults collected was 162 adults, and this increased gradually forward to reach a high index in 20 March, (12122 adults) and then the population decreased and declined in the 2nd week of April (3637 adults). In the first day of May, the population increased to 24254 adults and to 51521 adults in the first of June, this was followed by a decline in 2nd week of June (12628 adults) and then the population decreased and declined in the first of July (2778 adults) and then increased in the mid of July to 11112 adults.

Table 2: Total count of moths collected by the light trap during 2012-2013.

Early summer plantation Started in 25-1-2012					Nile plantation Started in 22-7-2012				
Month	Mean number of *T. absoluta*		Rate of increase of population	Average temperature °C	Month	Mean number of *T. absoluta*		Rate of increase of population	Average temperature °C
	Date	Count				Date	Count		
Feb. 2012	7/2	162	-	14	Aug.	1/8	8840	1.41	29.96
	21/2	556				15/8	10709		
	Total	718				total	19549		
Mar.	6/3	6566	26.03	16.19	Sep.	1/9	33842	2.36	27.46
	20/3	12122				15/9	12375		
	Total	18688				total	46217		
Apr.	3 / 4	3839	0.4	23.07	Oct.	1/10	11213	0.65	25.68
	17 / 4	3637				15/10	18942		
	Total	7476				total	30155		
May	1 / 5	24254	5.27	26.16	Nov.	1/11	9092	0.69	21.33
	15 / 5	15153				15/11	11617		
	Total	39407				total	20709		
Jun.	1/6	51521	1.63	28.83	Dec.	1/12	15658	0.86	16.35
	15/6	12628				15/12	2119		
	total	64149				Total	17777		
Jul.	1/7	2778	0.22	30	Jan. 2013	1/1	7003	0.4	14.58
	15/7	11112				15 / 1	5		
	Total	13890				Total	7008		

Rate of increase of population/ year 64149 / 718 = 89.34

On the other hand, the nile season started in 22/7/2012. *T. absoluta* population started to appear in the 1st week of August, where the number of adults collected was 8840 adults, and this increased gradually forward to reach a high index in early September (33842 adults) and then it decreased and declined in the first of October (11213 adults) and then increased in mid of October (18942 adults). In the first of December, the population of *T. absoluta* was 15658 adults and then declined to 2119 with an increase in the first of January 2013 to 7003 adults.

Generally, in both early summer and nile plantations, *T. absoluta* was observed immediately after tomato plantation and then its population increased gradually with the development of tomato plants till

flowering stage at which there is a peak of abundance. It appears that *T. absoluta* has 8 peaks around 2012. Three peaks in early summer plantations (the first half of 2012), the first peak occurred in the 3rd week of March, the second occurred in early May, the third in the first week of June (Fig. 1). Also, one peak was recorded in mid of July (between early summer and nile rotations) and four peaks of *T. absoluta* were recorded in the nile plantation. The first peak was in early September, the second was in mid of October, the third was in early December, while the fourth peak begins in January 2013.

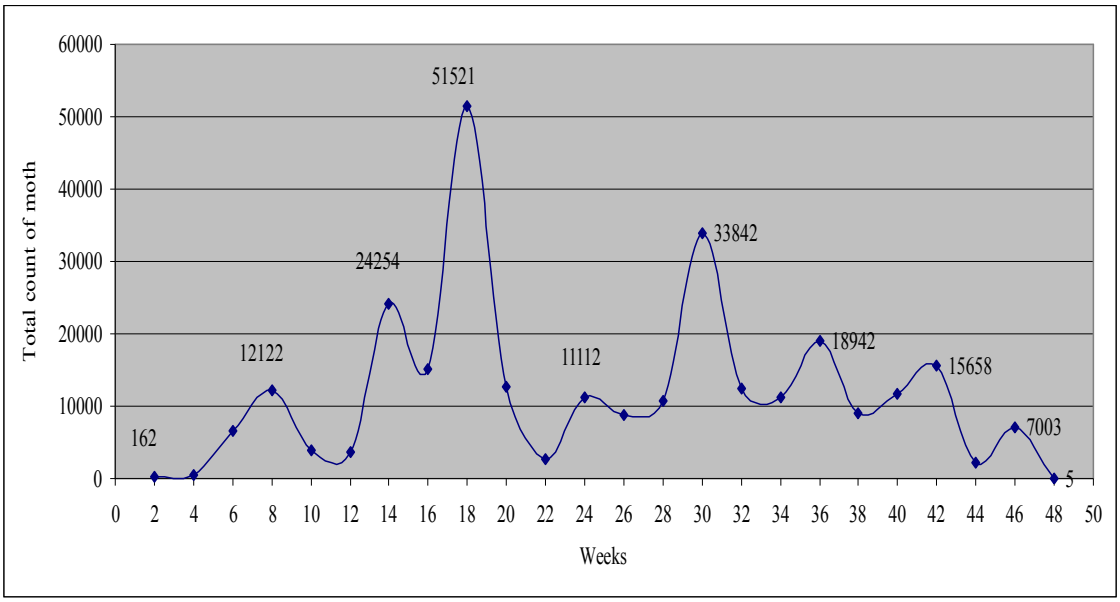

Fig. 1: Population fluctuation of *Tuta absoluta* using the light trap in Giza governorate during 2012-2013.

3-2- Seasonal variation and population fluctuation density of during 2013 - 2014.

The fluctuations in *T. absoluta* population in tomato cultivations during the summer and winter plantations, 2013-2014 in Giza governorate are shown in table (3) and illustrated in Fig. (2). The data show that, summer plantation started on mid of March 2013 and the number of collected adults was 2993 and increased gradually forward to reach its high index in mid April (17211 adults) then it decreased in the early May (11,701 adults). In the 2nd week of May, the population of *T. absoluta* increased to 15941 adults. Another increase in population occurred in the 1st of July (23887 adults) followed by a decline by end of July and then it increased in early August (13911 adults).

On the other hand, the winter plantation started in 19 September 2013. *T. absoluta* population started to appear in early of September before plantation, where the number of collected adults was 8607, and decreased gradually to reach 4891 adults in the mid of October and then it increased gradually to reach 11721 adults in the mid of November. In the first of December, the population of *T. absoluta* increased to 17311 adults then declined in the 2nd week to 8905 with an increase again in the mid of January 2014 to 12015 adults.

Generally, in both summer and winter plantations the population of *T. absoluta* started to appear before plantation and increased gradually with increasing the development of tomato plant till flowering stage at which the peak of population was noticed. It is noticed that, *T. absoluta* has five peaks in summer plantations (from March to the first of August), the first peak occurred in the first week of March, the second in the mid of April, the third in the mid of May, the fourth in early July and the fifth peak was recorded in the first of August (Fig. 2). Also, three peaks of *T. absoluta* were recorded in winter plantations. The first peak was in early September, the second was in early of December, the third was in the mid of January of 2014.

The rate of increase in the population density was calculated by dividing the total population in any month over that of the previous one. The data are shown in table (2). It appears that the highest value was 26.03 which occurred in March 2012 during which the environmental conditions seem to be optimal for the population of *T. absoluta* to increase under field conditions of Giza. The main climatic conditions prevailing during this period showed that means of temperature were 16.19 ˚C and means R.H. was 53.25 %.

During the year 2013, the highest value of the rate of increase of the insect population was 3.21 which occurred in April 2013 and during which the mean temperature was 21.13 ˚C and mean R.H. was 45.03 %.

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Table 3: Total count of moths collected by the light trap during 2013-2014.

Summer plantation Started in 14-3-2013					Winter plantation Started in 19-9-2013				
Month	Mean number of *T. absoluta*		Rate of increase of population	Average temperature °C	Month	Mean number of *T. absoluta*		Rate of increase of population	Average temperature °C
	Date	Count				Date	Count		
Feb. 2013	1/2	3702	-	16.32	Aug.	1/8	13911	0.65	28.77
	15/2	3819				15/8	6641		
	Total	7521				Total	20552		
Mar.	2/3	5307	1.1	20.1	Sep.	1/9	8607	0.61	27.7
	16/3	2993				15/9	3991		
	Total	8300				Total	12598		
Apr.	1 / 4	9457	3.21	21.13	Oct.	1/10	2271	0.57	23.84
	15 / 4	17211				15/10	4891		
	Total	26668				Total	7162		
May	1 / 5	11701	1.03	25.16	Nov.	1/11	10215	3.06	17.73
	15 / 5	15941				15/11	11721		
	Total	27642				Total	21936		
Jun.	1/6	8766	0.74	27.3	Dec.	1/12	17311	1.2	14.81
	15/6	11721				15/12	8905		
	Total	20487				Total	26216		
Jul.	1/7	23887	1.54	29.26	Jan. 2014	1/1	11077	0.88	15.7
	15/7	7561				15/1	12015		
	Total	31448				Total	23092		

Rate of increase of population / year 31448 / 7162 = 4.4

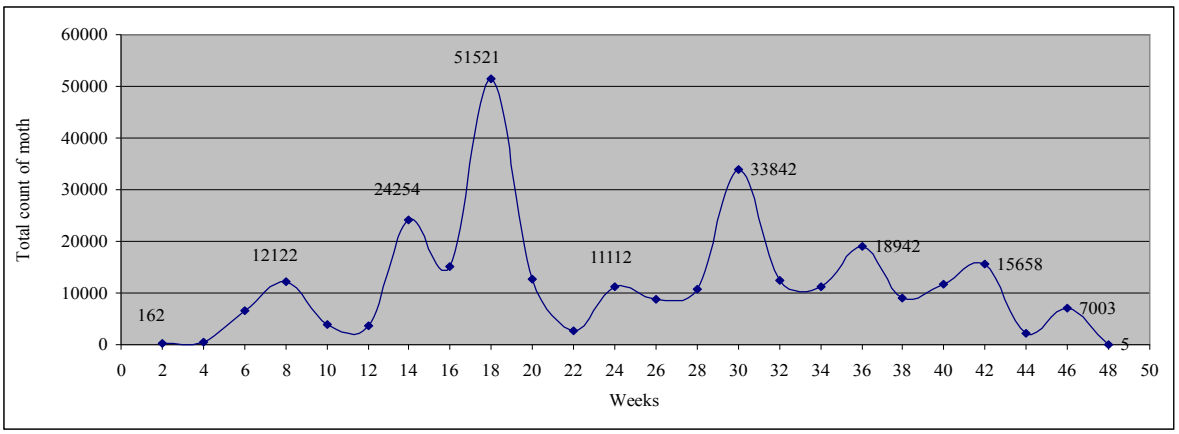

Fig. 2: Population fluctuation of *Tuta absoluta* using light traps in Giza governorate during 2013-2014.

The average of annual fluctuation as calculated by dividing the maximum population by the minimum population showed to be 89.34 during 2012 and 4.4 during 2013. This may be due to the fact that the insect population under Egyptian field conditions was low in the second year 2013 as compared to the year 2012.

Discussion:

The foregoing investigations indicate that the incubation period of the eggs, larval and pupal duration were significantly shortened as the temperature increased from 15 to 30 ˚C. Following pupation, males and females emerged but the female longevity was longer compared to the male and the longevity of both sexes decreased with the temperature increase. The pre-oviposition period was short and ranged from 2.3 to 4.6 days depending on temperature. The egg production showed to be affected by temperature variation and the highest production occurred at 20 ˚C being 162 ± 30.94 eggs/female, with slight decrease when temperature decreased to 15˚C. While, at higher temperatures, the mean production of eggs was decreased. From the data obtained, the life cycle of the male was shorter than the female being 90.63 ± 1.64 days compared to 94.56 ± 1.2 days in the female. This relation holds the same at all tested temperatures. Data reported by previous authors agree to a great extent with our findings e.g. Fernandez, Montagne 1990, Barrientos *et al*. 1998, Estay, 2000, Mahdi *et al*. 2011, Andrew *et al*. 2013.

The moths collected by light trap during two years and during different tomato rotations showed the occurrence of 8 peaks of *T. absoluta* moths abundance during summer and nile rotations of 2012 and also during summer and winter rotations of 2013. These peaks correspond to the number of annual generations of the insect in the experimental area. These dates can be made use off to carry on the control applications.

Data from the present investigation coincide with those of Hoffmann *et al.* 1990 who stated that the greatest activity for tomato fruit worm (*Heliothis zea*) occurred in August and September. Also, Tari *et al.* 2009 demonstrated that the highest population of *T. absoluta* males was recorded during the end of March, whereas the lowest population was recorded during November. Nannini *et al*. 2010 reported the highest population of *T. absoluta* moths in Italy during September-October. Lazgeen *et al*. 2013 who recorded the adult of *T. absoluta* from early June until September in Summel region, Iraq with the maximum number of collected during September 2012.

The rate of increase in the insect population occurred in March 2012 and April 2013 and the mean temperatures prevailing ranged between 16.10 – 21.13 ˚C.

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