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Life Table of the Tomato Leaf Miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

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Abstract: The life history of the tomato leaf miner, *Tuta absoluta* (Meyrick) [Lepidoptera:Gelechiidae)] was studied under the laboratory conditions in 2013 year. For this purpose, development and survival of immature stages, adult longevity, fecundity and ovipositon period of *T. absoluta* were studied. According to the results, it was determined that the width of the head capsule of larvae for first, second, third and fourth were 0.15, 0.29, 0.39 and 0.75 mm respectively. It was determined that the length of egg hatching was 4.10 days. Total period of larvae instar was 10.97 days. The period of pupae development was 9.53 days. Fecundity of *T. absoluta* was found 141.16 eggs/female. Preoviposition period was 1.28 days. Oviposition and postoviposition periods were 7.88 and 5.52 days respectively. The intrinsic rate of increase (r_m), finite population increase (λ), net reproductive rate (*Ro*) and mean generation time (*To*) of *T. absoluta* were 0.132 day^{-1}, 1.141day^{-1}, 42.01 and 28.25 days respectively. The life expectancy of a newborn egg was 42.60 days. All of experiments were conducted in a climate chamber at 25±1ºC, relative humidity 65±5% and under long daylight (16L:8D).

Key words: Life table, population parameters, *Tuta absoluta*

Özet: *Tuta absoluta* (Meyrick) [Lepidoptera:Gelechiidae)]'nın hayat tablosu laboratuar koşullarında ortaya konulmuştur. Bu amaçla, *T. absoluta*'nın ergin öncesi dönemleri gelişme süreleri ve ölüm oranları, ergin hayat uzunluğu, üreme gücü ve ovipzisyon süresi belirlenmiştir. Elde edilen sonuçlara göre, birinci, ikinci, üçüncü ve dördüncü larva dönemi kafa kapsülleri genişliği sırasıyla 0.15, 0.29, 0.39 and 0.75 mm olarak belirlenmiştir. Yumurta açılım süresi 4.10, toplam larva dönemi süresi 10.97 ve pupa dönemi süresi 9.53 gün olarak belirlenmiştir. Bir dişinin bıraktığı toplam yumurta sayısı 141.16 adet olmuştur. Preovipozisyon, ovipozisyon ve postovipozisyon sürelerinin sırasıyla 1.28, 7.88 ve 5.52 gün olduğu tespit edilmiştir. Kalıtsal üreme yeteneği, r_m=0.132 gün^{-1}, üreme gücü sınırı, λ=1.141gün^{-1}, net üreme gücü, r_o=042.01, ortalama döl süresinin, T_o=28.25 gün olduğu ortaya konulmuştur. Yumurtadan ergine geçen süre 42.60 gün olarak tespit edilmiştir. Denemeler 25±1ºC sıcaklık, %65±5 orantılı nem ve 16 saat gün uzunluğuna sahip iklim odasında yapılmıştır.

Anahtar kelimeler: Hayat tablosu, popülasyon parametreleri, *Tuta absoluta*

1. Introduction

The tomato leaf miner *Tuta absoluta* (Meyrick) [Lepidoptera:Gelechiidae)] has been reported in Turkey since 2009, quickly becoming one of the major pests of the tomato crop (Kılıç 2010). *T. absoluta* is a very harmful insect pest with a strong preference for tomato plants. It originates from South America where it has been considered a key pest since the 1980s (EPPO 2005). *T. absoluta* is a multivoltine species, which rapidly develops in favorable environmental conditions, with overlapping life cycles (Guenaoui et al. 2010). Although *T. absoluta* is an oligophagous pest with a strong preference for tomato, it can also attack the aerial parts of potato, eggplant, pepino, tobacco and solanaceous weeds (Notz 1992).

T. absoluta is a major pest of both field and greenhouse tomatoes. It deposits eggs usually on the underside of leaves, stems and to a lesser extent on fruits. After hatching the larvae mine the leaves producing large galleries and feed on mesopyllic tissue. The larvae can destroy up to 100% of the leaf surface and damage 50-100% of fruits in severely attacked fields (EPPO 2005).

Scientists are working on the development of new control strategies against this pests (Braham and Hajji 2012, Abbes and Chermiti 2011). It is necessary to know the population ecology of the target species to effectively control the pest population.

The life table of a population is important to control pests because it gives the most comprehensive description on the growth, survival and fecundity. The life table studies of *T. absoluta* have been reported by some authors (Miranda et al. 1998, Pereyra and Sanchez 2006). The data from these studies include laboratory and field observations on the development time and fecundity on tomato plant. However, there is no information about life table detailed parameters for *T. absoluta.* Therefore, the objective of this study was to determine the effect of tomato plants on the development, survival, reproduction and life table parameters of the *T. absoluta* in the laboratory.

2. Materials and Methods

Host Plant: The foliage of tomato plants was used in this study. Plants used in this laboratory experiment were grown under greenhouse conditions (Semiz and Yurtseven, 2010).

Tuta absoluta**:** A laboratory population of *T. absoluta* from field-collected larvae from tomato areas in Beypazari, Ankara-Turkey, was used in this study. This culture was kept in 50x30x30 cm wooden rearing cages lined with tulle. Newly emerged adults were transferred into another cage containing tomato leaves. Eggs laid on tomato leaves were kept in a climate chamber (25±1ºC, 65±5% R:H.; photoperiod: 16L:8D).

Development and Survival of Immature Stages: Ten female and male pupa were collected from larvae reared on the tomato plant. When adults emerged, moths were provided with 10% sucrose solution and allowed to mate for 1 day in containers (50x30x30 cm diameter). Then hundred eggs laid on the same day were placed into petri dishes (3.5 cm diameter) containing moisturized disc cotton and tomato leaf discs (3 cm diameter). Each egg was placed in a separate petri dish. These eggs were observed for the hatching rate (%) and the number of emerging larvae. Fresh foliage was provided for newly emerged larvae and observed daily through pupation and adult emergence. Individual insects were checked daily for development and survival. Egg period (days from egg laying to hatching neonate larvae), first larva instar period (days from hatching of egg to first head capsule), second larvae instar period (days from first head capsule to second capsule), third larvae instar period (days from second head capsule to third capsule), fourth larvae instar period (days from third head capsule to pupa stage, larva instar period (days from first instar to pupae), pupae period (days from pupae to adult emergence) were recorded. Only individuals that survived to the adult stage were included in the analysis.

To establish the larvae stages period, the width of the head capsule was measured using a circular micrometer placed into the ocular of a dissecting microscope, on larvae during their different developmental stages. To determine the period of larvae stage, totally 15 larva were used for each period. The sex of individual was distinguished as male or female at the pupae stage.

Adult Longevity, Fecundity and Oviposition: When emerged, adults were transferred into wooden rearing cages (15x15x10 cm) lined with tulle, containing tomato leaves, and supplied with 10% sucrose solution. One female and two male were placed into each cage. The experiment was repeated 25 times. Experiments were observed daily and fresh foliage provided as required. During the experiment, adult mortality and the number of eggs deposited were recorded until the death of each adult.

Life Table Analysis: The development times of immature individuals and reproduction were combined to create life tables. The life table *T. absoluta* was analyzed according to the theory of stage, two-sex life table (Chi and Liu 1985; Chi 1988) by using the computer program TWOSEX. The age-stage survival rate, the distribution of mortality rate, the age-stage life expectancy and stable age-stage distribution were calculated. The intrinsic rate of increase (r_m) the net reproductive rate (R_o), the mean generation time (T_o) and the finite of population increase (λ), were calculated by using the Jackknife method (Sokal and Rohlf 1995, Meyer et al.1986).

All of experiments were conducted in a climate chamber (25±1ºC, 65±5% R:H.; photoperiod: 16L:8D).

3. Results and Discussion

Survivorship, development and longevity: The width of the head capsule for each instar larva is given in Table 1. It was determined that the width of the head capsule of larvae first, second, third and fourth periods were 0.15, 0.29, 0.39 and 0.75mm respectively. There was no publishing about this subject.

Table 1. *The width of the head capsule for each instar larva of Tuta absoluta at 25-26° C and 60-70% R.H.*

Larva Stage	n	The width of the head capsule (mm) Mean±SE
L_1	15	0.15±0.004
L_2	15	0.29±0.011
L_3	15	0.39±0.007
L_4	15	0.75±0.003

n= number of individuals

Table 2 and Fig. 1 show the development period and survival of *T. absoluta*. All eggs hatched successfully. It was determined that the length of egg hatching was 4.10 days. Previous studies found that the period of egg hatching was 4-5 days (EPPO 2005, Torrest et al. 2001). Also it was found that the period of larvae stage, first, second, third and fourth instar were 2.49, 2.32, 2.52 and 3.79 days respectively. Total period of larvae instar was 10.97 days. The period of pupae development was 9.53 days. There were no significant differences in the developmental times of the egg, larvae and pupae stages between sexes [(egg: -1.67; df=51;); (larvae:t=405; df=206; p=0.086); (pupae: t=-0.441; df=51; p=0.661); (adult: t=-0.666; df=51; p=0.102)]. No other studies were found to determine separately the larvae instar stages. However, some studies about period of larvae instar were found. Results determined from this study were similar to those reported for *T. absoluta.* Torrest et al. (2001) who stated the period of larvae instar of *T. absoluta* was 12 and 16 days at 27ºC. Pereyra and Sanches (2006) reported that the period of larvae instar of *T. absoluta* was 12.14 days at 25±1ºC. It was determined that that the period of larvae instar of *T. absoluta* was 13-15 days (EPPO 2005). It was found that the period of pupae instar of *T. absoluta* was 9.53 days. Torrest et al. (2001) found that period of pupae instar of *T. absoluta* was 7-9 days. The means of development period from egg to adult was 30.18 days. Under optimal conditions *T. absoluta* developed in about 30 days (EPPO 2005). Barriontes et al. (1998) reported that average development time of *T absoluta* was 23.8 days at 27.1ºC. Cuthbertson (2011) reported that the development from egg to adult took 35 days at 25ºC.

Table 2. *Preadult development period (days) of Tuta absoluta at 25-26° C and 60-70% R.H.*

Stage	All	n	Female	n	Male	n	Survival (%)
Egg	4.10±0.08	84	3.96±0.14	25	4.29±0.14	28	100
L_1	2.49±0.09	75	2.56±0.13	25	2.18±0.10	28	89.29
L_2	2.32±0.07	66	2.20±0.10	25	2.36±0.13	28	78.57
L_3	2.52±0.07	61	2.52±0.10	25	2.36±0.11	28	72.62
L_4	3.79±0.19	56	3.72±0.33	25	3.79±0.22	28	66.67
Total larvae span	10.97±0.92	56	11.00±0.16	25	10.87±0.11	28	76.78
Pupae	9.53±0.25	53	9.48±0.38	25	9.57±0.36	28	63.10
Total life span	30.18±1.70	84	42.60±1.30	25	40.36±0.66	28	-

n:number of individuals

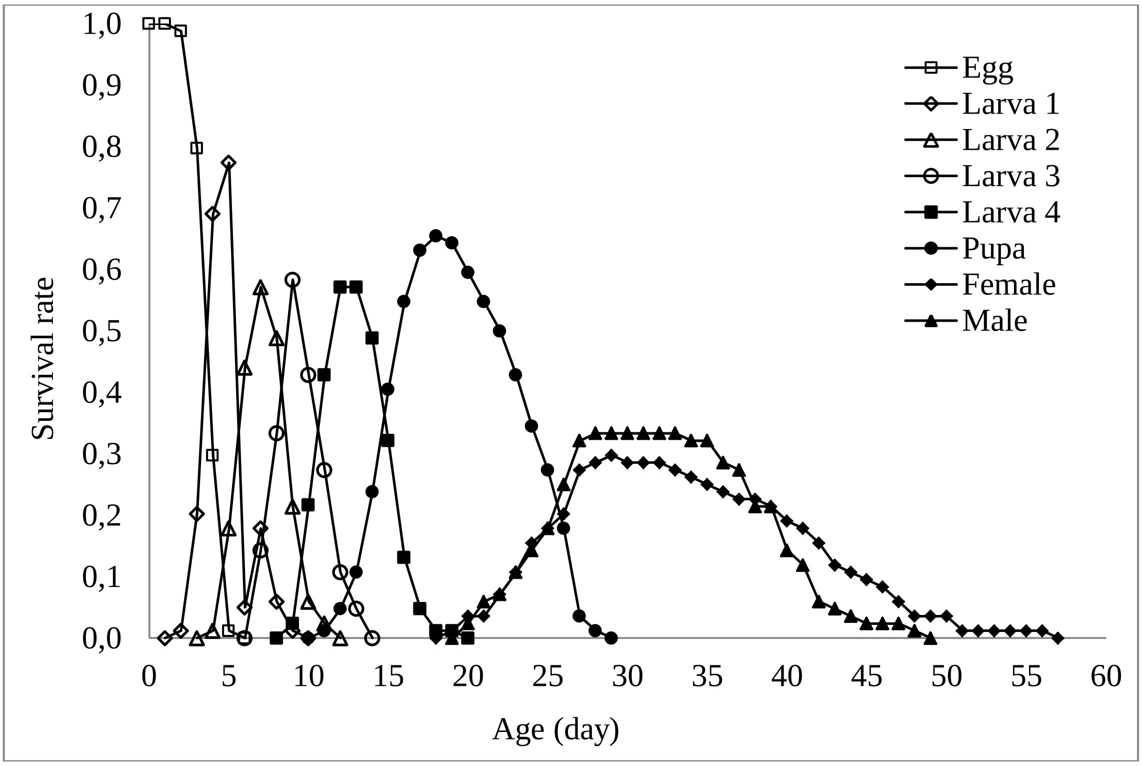

Figure 1. *The age- stage survival rate (sij) of Tuta absoluta at 25-26° C and 60-70% R.H.*

According to the development stage, the survival of the egg stage was 100%. The survival rate of first, second, third and fourth larvae stage was 89.29, 78.57, 72.62 and 66.67% respectively. Also, it was found that the survival rate of pupa was 63.10%.

In this study, it was determined that usually males were more than female individuals (although more or less 1:1 ratio was maintained). Cuthbertson (2011) reported that males were more than females.

Fecundity and adult longevity: It was found that adult longevity for male and female individuals were 15.8 days and 18.16 days respectively but it was not statistically (t=1.53; p=0.134) different. Fecundity of *T. absoluta* was found 141.16 eggs/female. Preoviposition period was 1.28 days. Oviposition and postoviposition periods were 7.88 and 5.52 days respectively (Table 3). Fig. 2 illustrates the age-specific survival rate(l_x), female age-stage specific fecundity (m_x) and the age-specific maternity ($l_x m_x$). The age-specific survival rate (*lx*) gives the probability that a newborn will survive to age x and fecundity was calculated by including all individuals of both sexes. Similarly, the age-specific fecundity (m_x) and the age-specific maternity ($l_x m_x$) were calculated by including all individuals of both sexes. The curve of *lx* was a simplified version of the curves in Fig. 2. The m_x curve was plotted on the age since birth. Also, it was observed that the period of mating of *T. absoluta* lasted 5-6 hours. Estay (2006) found adult of *T. absoluta* lifespan ranged between 10 - 15 days for females and 6 -7 days for males. These results were different from those obtained within the current study. Though the adult *T. absoluta* were not sexed in the longevity study, they lived much longer than 15 days. Females lived longer than males, allowing them to be sexually mature when the males emerge (Fernandez and Montagne 1990). Female fecundity ranged from 60 to 120 eggs and female longevity from 10 and 22 days (Torrest et al. 2001). It was stated that females mate only once a day and were able to mate up to six times during their lifespan, with a single mating bout lasting 4-5 hours. The oviposition period was 7 days after first mating, and females laid 76% of their eggs at that time, with a maximum life time fecundity of 260 eggs per female (Uchoa-Fernandes et al. 1995). Pereyra and Sanches (2006) reported that fecundity (number eggs/female) was 132. 78.

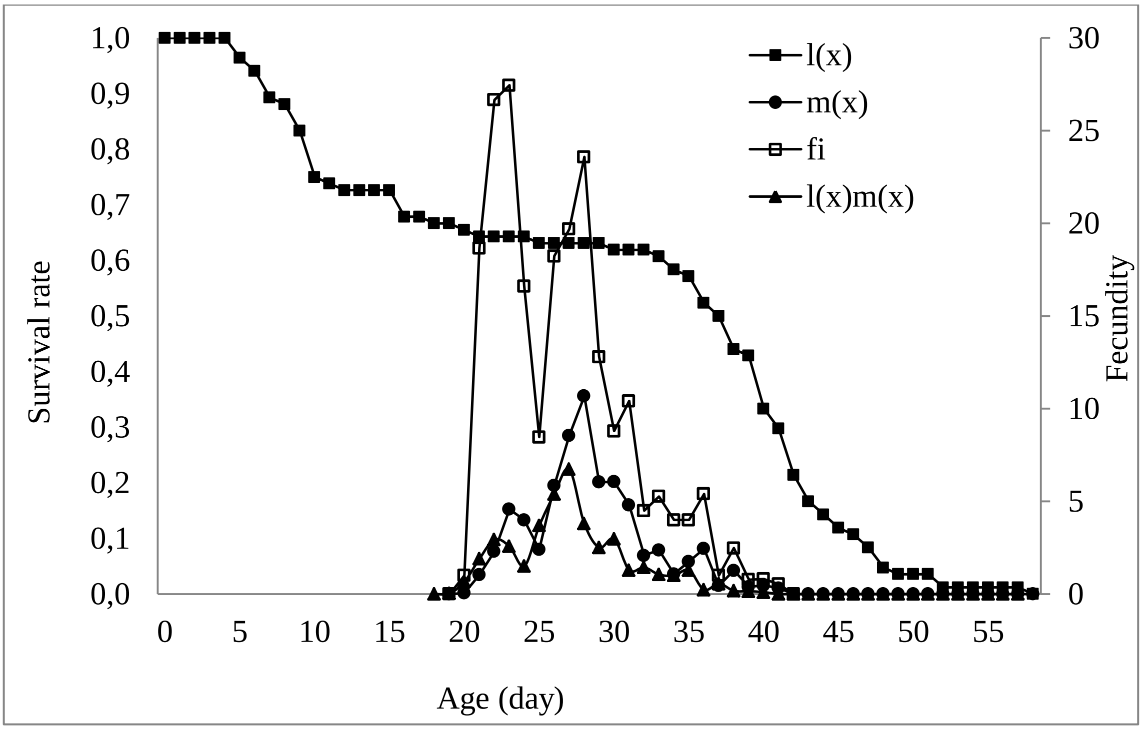

Figure 2. *The age-specific survival rate (lx), the age-stage fecundity of female (fi₄), the age-specific fecundity of the cohort (mx) and the age-specific maternity (lxmx) of Tuta absoluta at 25-26° C and 60-70% R.H.*

The mortality rates and life expectancy: Fig. 3 and 4 illustrate the distribution of mortality during the whole life span of *T. absoluta*. There was no mortality in the egg stage. First, second, third, fourth larvae and pupae stage mortalities were 10.7, 10.7, 6.0, 6.0 and 3.6%, respectively. Out of 100 the eggs, 25 females and 28 males were obtained.

Based on the age-stage survival rate, the life expectancy for each age-stage interval was calculated to predict the future life of the population (Fig.5). The life expectancy (e_{ij}) is the time that an individual of age *i* and stage is expected to live. It was observed that the life expectancy of the female adult was much higher than that of the male adult as reported in Table 2 where the adult longevity of male was much shorter than that of the female.

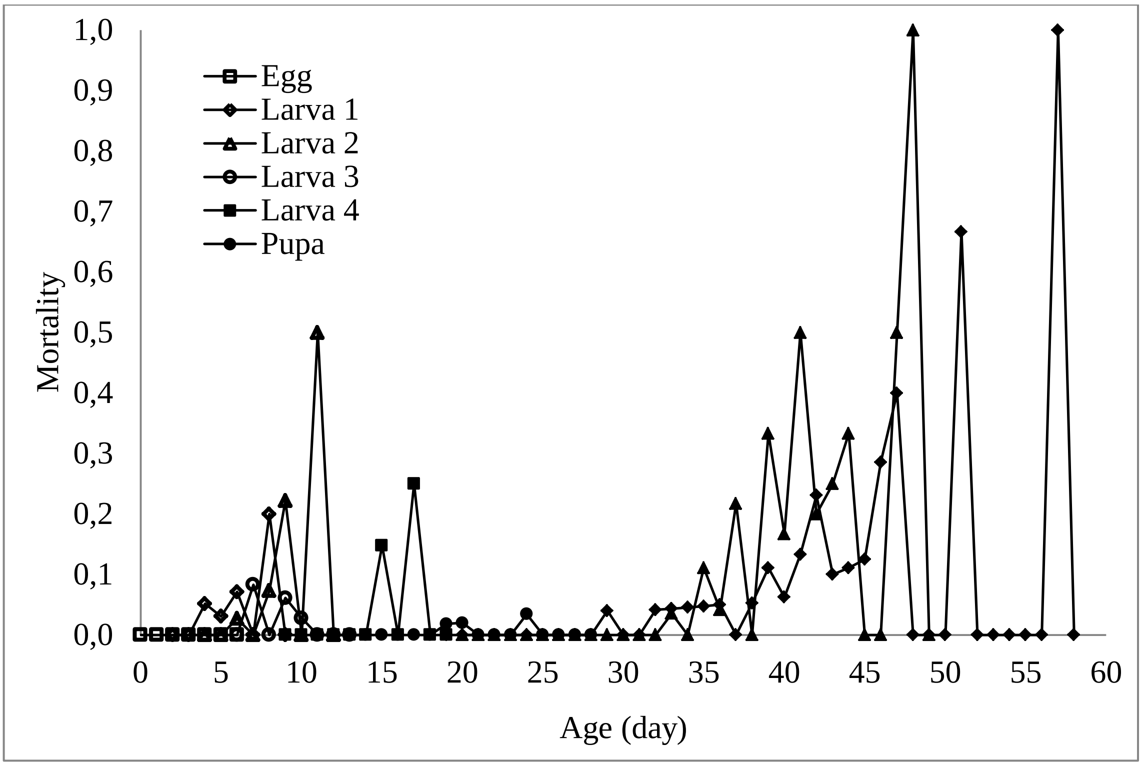

Figure 3. *The age-stage specific mortality of Tuta absoluta. at 25-26° C and 60-70% R.H.*

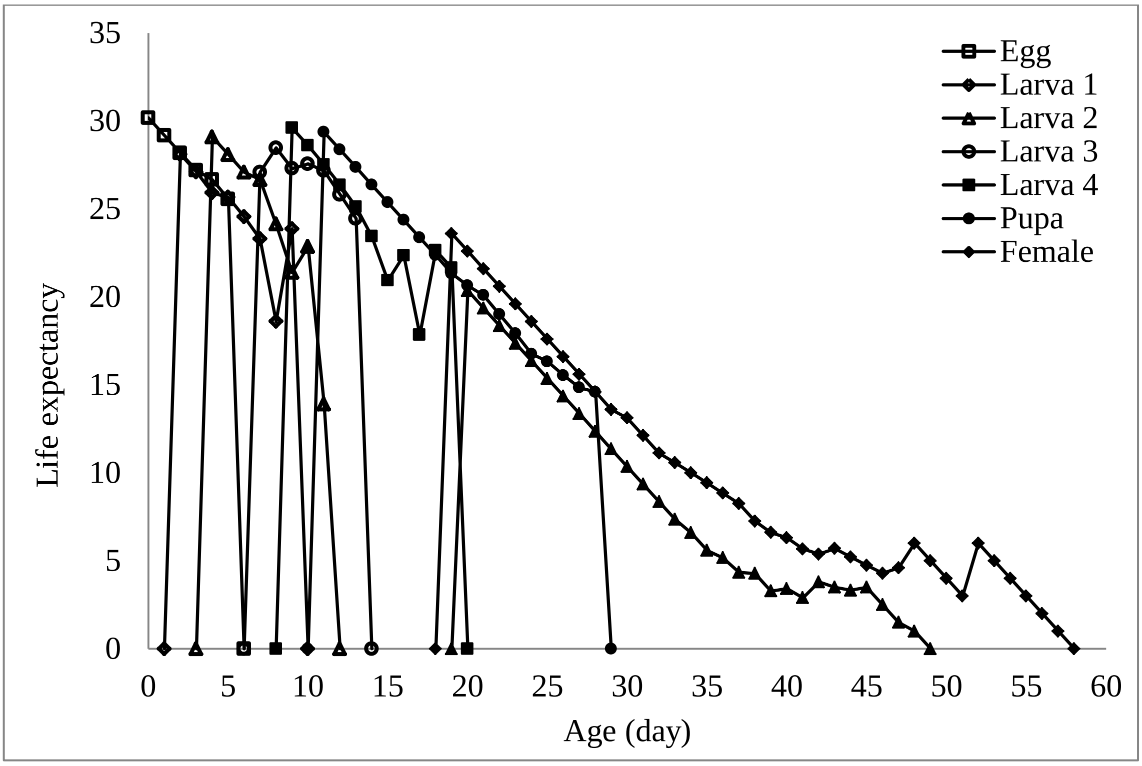

Figure 4. *The age-specific life expectancy (eij) of Tuta absoluta at 25-26° C and 60-70% R.H.*

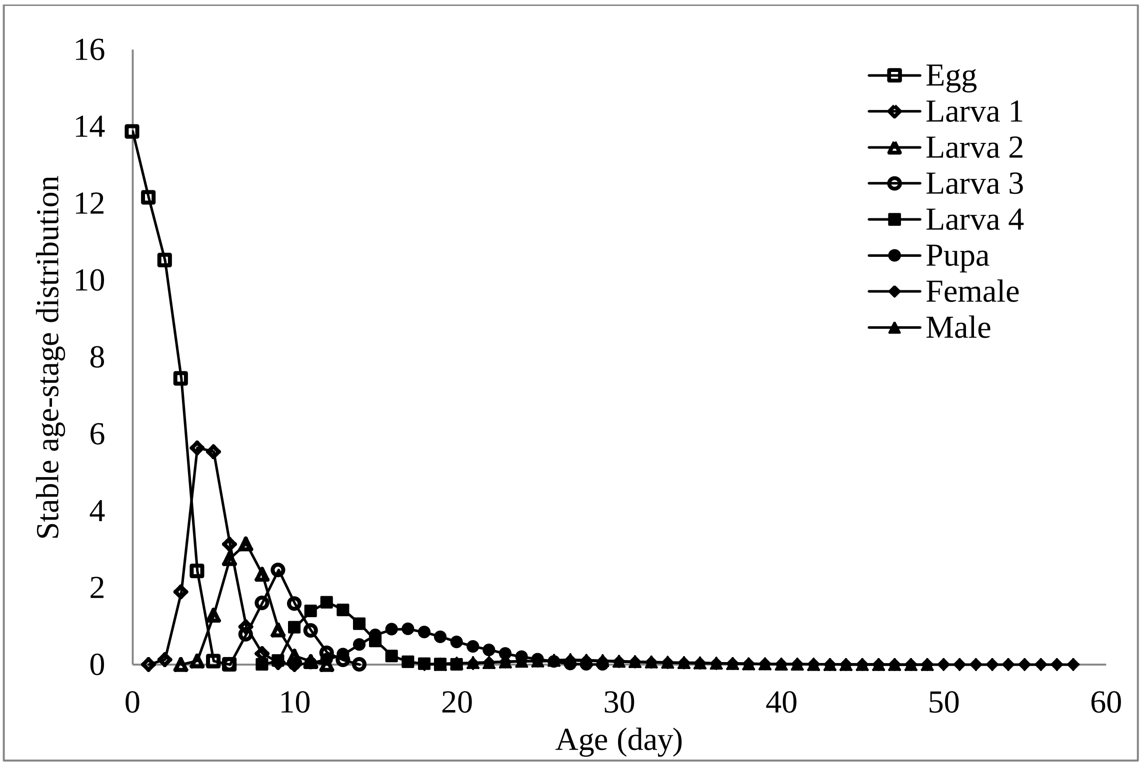

Figure 5. *The stable age-stage distribution of Tuta absoluta at 25-26° C and 60-70% R.H.*

The life table analysis: Population parameters calculated by using the age-stage, two-sex life table are listed in Table 4. The intrinsic rate of increase (r_m), the finite rate of increase (λ), net reproductive rate (R_o) and the mean generation time (T_o) of *T. absoluta* were 0.132 day^{-1}, 1.141 day^{-1}, 42.01 offspring/individual, and 28.25 days, respectively. These results suggest that if the population reaches the stable age-stage distribution and if there are no mortality factors other than the physiological ones, *T. absoluta* population can multiply 1.141 times day-^{1} with an average of 28.25 days with an exponential rate of 0.132 per day. Similar results were obtained by Pereyra and Sanches (2006) who found that the population parameters of *T. absoluta* were the intrinsic rate of increase (r_m= 0.14), the net reproductive rate (*Ro*=48.92) and the mean generation time (*To*=27.98). The intrinsic rate of increase and the mean generation time reflect the suitability of the host-plant (Tsai 1998) as, among other factors, survivorship and fecundity are affected by the host-plant nutritional value. Survival curves of cohorts reared on tomato maintained high values until the reproductive age, suggesting an elevated capacity of population increase. A shorter generation time (*To*) on tomato would also reduce the time of exposure of *T. absoluta* to natural enemies under field conditions (Price et al. 1980). This, in turn, means a better fitness in terms of survival and fecundity and an increased probability of leaving offspring.

In comparison with other species of moths, Chi (2010) found the following parameters for *Phthorimaea operculella* Zeller (Lepidoptera:Gelechiidae): net reproductive rate (*Ro*=69.7), the mean generation time (*To*=31.2) and the intrinsic rate of increase (r_m=0.136) were. The highest reproductive rate was observed on Burren potatoes (50.74±2.45), although there was one statistical group for net reproduction rate (R_0). The mean generation time (T_0) was the longest on the Agria potatoes. The mean generation time has reciprocal relation with r_m; subsequently, the lowest intrinsic rate of increase was observed on Agria potatoes. The highest and lowest r_m value was observed on Burren and Agria potatoes, respectively (Golizadeh and Razmjou 2010). The population growth parameters of *P. operculella* revealed that the net reproductive rate (R_o) varied from 1.36 to 7.9, the mean of generation length from 20.94 to 28.81 days, the innate capacity of natural increase from 0.0142 to 0.0790, and the finite rate of increase from 1.012 to 1.08 in six generations (Trivedi et al. 1994).

Fisher (1930) stated that the life table analyses reveal the contribution of an individual to the growth of future population. Fig. 6 illustrated the age-stage reproductive value of *T. absoluta*. If an individual becomes a female adult, its reproductive value increases dramatically. The female second day of age gave a maximal reproductive value of 94. With the increasing awareness of the importance of sustainable agriculture and environmentally friendly pest management, life table studies on key pests and their practical application in pest control are certainly and urgently worth pursuing.

Table 3. *Adult longevity (days), and fecundity (eggs/female) of Tuta absoluta at 25-26° C and 60-70% R.H .*

Parameter	Stage	Mean±SE n=25
Adult longevity (days)	Male	15.82±0.527
	Female	18.16±1.365
Adult pre-oviposition period (APOP)	Female	1.28±0.135
Oviposition period	Female	7.88±0.628
Fecundity (F)(eggs/female)	Female	141.16±12.17
Adult-post-ovipositon period	Female	5.52±0.854

Table 4.*The population parameters of Tuta absoluta at 25-26° C and 60-70% R.H .*

Population parameter	Calculated by using all individuals
The intrinsic rate of increase (r_m day $^{-1}$)	0.132
The finite rate of increase (λ ; day $^{-1}$)	1.141
The net reproductive rate (Ro) (offspring/individual)	42.01
The mean generation time (To; days)	28.25

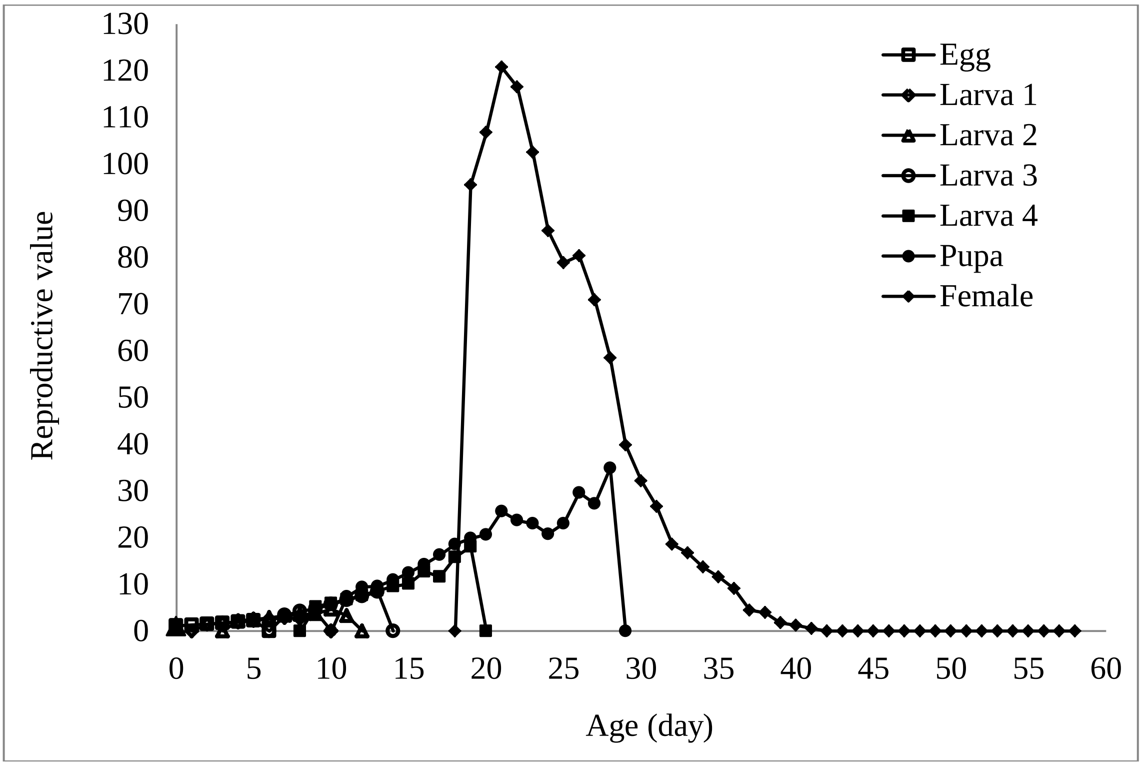

Figure 6. *The age-stage reproductive value (vxj) of Tuta absoluta at 25-26° C and 60-70% R.H.*

4. Conclusion

Life table give the most comprehensive description of the age-specific survival rate and fecundity of insect populations. The information can be used to project the population growth and stage differentiation. The life table is also most important basis for quantitative and qualitative study of population ecology. It can be used to compare different insects under the same conditions.

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