Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(6): 546-549

Received: 03-09-2018
Accepted: 04-10-2018

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Age specific fecundity life table of South American tomato leaf miner, *Tuta absoluta* (Meyrick) on tomato

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Abstract
The age specific fecundity life table studies of *Tuta absoluta* (Meyrick) were conducted at room temperature 25 ± 2 °C and 75 ± 2 percent RH on tomato in Department of Entomology, S.V. Agricultural College, Tirupati. Age specific fecundity life table of *T. absoluta* revealed that the net reproductive rate (R_0), intrinsic rate of increase (rm), mean generation time (Tc), corrected generation time (T), finite rate of increase (λ) and weekly multiplication of population (λ^7) were R_0 = 40.18 individuals per female, 0.19 (female progeny/female/day), Tc = 30.16 days, T = 28.94 days, λ = 1.20 and λ^7 = 35.83, respectively.

Keywords: South American tomato leaf miner, *Tuta absoluta*, life table

1. Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated and consumed food crops among the vegetables in India. It is an essential raw material for a variety of food processing industries. Tomato is rich in minerals, vitamins and antioxidants that are important to a well-balanced diet. It is also an important dietary component because it contains high levels of lycopene, an antioxidant that reduces the risk associated with several cancers and neurodegenerative diseases. It is used as a salad, paste, peeled tomatoes, diced products, juice, sauces and soups (Srinivasan, 2010) [21].

Tomato production has been fluctuating many biotic and abiotic constraints. Prominent among biotic constraints are pests and diseases which reduce yields and the quality of marketable fruits. Recently, South American tomato leaf miner or pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), is emerging as major pest and causing extensive damage up to cent percent yield loss in India particularly under South Indian field conditions. It has been reported from different parts of India throughout the year though the incidence level varies (Sridhar *et al.*, 2014) [22].

In India, *T. absoluta* was first reported during October, 2014 infesting tomato fields in Pune, Ahmednagar, Dhule, Jalgaon, Nashik and Satara districts of Maharashtra (Shashank *et al.*, 2015) [17]. Subsequently, pest was recorded from Karnataka (Sridhar *et al.*, 2014 [10], Kalleshwaraswamy *et al.*, 2015 [10] and Ballal *et al.*, 2016 [13], Tamil Nadu (Shanmugam *et al.*, 2016 [14] and Ballal *et al.*, 2016 [3], Andhra Pradesh and Telangana (Anitha *et al.*, 2015) [1], New Delhi (Shashank *et al.*, 2016) [18], Gujarat (Ballal *et al.*, 2016) [3], Madhya Pradesh (Swathi *et al.*, 2017) [22], Punjab (Sandeep *et al.*, 2017) [13], Meghalaya (Sankarganesh *et al.*,2017) [14] and Himachal Pradesh (Sharma and Gavkare, 2017) [16] causing severe damage to tomato in invaded areas in India.

T. absoluta is a microlepidopteran moth with high reproductive potential. The pest is multivoltine having nearly 10 to 12 generations per year. Females lay eggs singly on the upper and lower surface of the leaf, buds and calyxes of the green fruits. A single female can lay a total of about 260 eggs during its lifetime. Larvae in the initial instars were cream colored, later changes from greenish (second instar) to light pink (fourth instar). Larval period is most damaging period which completed within 12 to 15 days (Estay, 2000) [8]. Pupation takes place in the soil, on the leaf surface or within the mines, depending on the environmental conditions. Adults were nocturnal and hide during the day between leaves. The biological cycle of *T. absoluta* is completed in 29 to 38 days, depending on the environmental conditions. The most important identifying characters are the filiform antennae, silvery-grey scales and

characteristic black spots present in anterior wing (Simala *et al.*, 2011) [19]. It is a new devastating pest of tomato in India and in Andhra Pradesh, studies on age specific fecundity life table of this pest is lacking. Knowledge on age specific fecundity life table provide a concise summary of mortality and reproductive schedules and help to explain why certain species proliferate in a particular environment. The age specific fecundity life table of *T. absoluta* was studied under laboratory conditions.

2. Materials and Methods

The age specific fecundity life table studies of *T. absoluta* were conducted at room temperature 25 ± 2 °C and 75 ± 2 percent RH on tomato hybrid Sweakar-448 in Insectary, Department of Entomology, S.V. Agricultural College, Tirupati.

Freshly emerged adults (male and female) of *T. absoluta* were collected from the nucleus culture and were released into the separate cages (30 x 30 x 30 cm) for mating. Twenty days old tomato seedlings were provided for oviposition. Fresh seedlings were provided after every 24 hr until the completion of oviposition by the adults. The plant parts containing the freshly laid eggs were removed from the tomato seedlings with the brush and used to study age specific fecundity life table parameters. Age-specific fecundity life table for female *T. absoluta* was constructed by the methods of Deevey (1947) [6], Morris and Miller (1954) [11] and Birch (1948) [4].

The study was initiated with 50 eggs which were laid in a single day. Each egg was placed separately on tomato leaves in petri plates. The newly hatched larvae were allowed to develop till pupation and adult emergence. Mortality from hatching of eggs to emergence of adults was recorded daily. The emerging adults were sexed and were used to study the fecundity of females. Fecundity of the female was noted daily from adult emergence to death.

The age specific fecundity life table was constructed from the column x and lx according to Birch (1948) [4].

x: Age group or stage of the development of insect

In this life table, the lx column represented the number of females as a fraction of initial size of cohort.

$$lx = \frac{\text{Number of females alive}}{\text{Number of eggs at the initial stage of the cohort (x)}}$$

The mx represented the female offspring at the age interval

$$mx = \frac{\text{Average fecundity at age interval 'x'} \times (lx) \times \text{Number of females}}{\text{Number of males}}$$

The column lx and mx were multiplied to get the total number of female births (lxmx) in each age interval.

2.1 Age specific fecundity life table parameters of *T. absoluta*

Net reproductive rate (R_o): The total number of female off spring's produced per female during single generation = ∑lxmx

$$\text{Mean generation time } (T_c) \text{ (days)} = T_c = \frac{\sum lxmx.x}{\sum lxmx}$$

$$\text{Corrected generation time (days) } (T_c) = \frac{\log_e R_o}{r_m}$$

Where e = natural log 2.71828

The above r was an approximate value.

A more accurate measure of determining the value of intrinsic rate of increase 'rm' was done by establishing the following relationship.

$\sum e^{7-rx}$. lxmx = e^7 = 1097

Where e = natural log = 2.71828

Intrinsic rate of increase 'rm' value= Σe^{7}-rm × lxmx =1096.6

Taking two trial values on either side of rc differing in the second decimal place, the two trial e7-rx lxmx were plotted on horizontal axis against their respective r values on the vertical axis with a line drawn from the value of e7-rx lxmx=1096.6. The point of intersection gave the precise value of r_m which was expressed as female progeny/female/day.

From the 'rm' value, the corrected generation time (T_c), finite rate of increase (λ) and weekly rate of multiplication (λ^7) were derived with the following formulae:

$$\text{Corrected generation time (days) } (T_c) = \frac{\log_e R_o}{r_m}$$

Finite rate of increase (λ) (females/female/day) = e^{rm}

Weekly rate of multiplication (λ^7) = $(e^{rm})^7$

3. Results and Discussion

The age specific fecundity life table of *T. absoluta* was studied on tomato hybrid (Sweakar-448) under laboratory conditions at mean temperature (25 ± 2 °C) and relative humidity (75 ± 2%). Data on survival, mortality, fecundity and total number of females emerged were recorded. By using the above observations, age specific fecundity life table was constructed. The data pertaining to age specific fecundity life table are presented in Tables 1 and 2.

The data revealed that the age of adult female first egg laying by female was at 27 days and the age of fifty percent egg laying at 31st day, last egg laying at 34th day. The oviposition period was lasted for 8 days. The net reproductive rate (Ro) of *T. absoluta* was 40.18 individuals per female (Table 1). The result of present study on the net reproductive rate was comparable with the findings of Erdogan and Babaroglu (2014) [7] who reported the net reproductive rate as (Ro) 42.01 offspring per individual at 25 °C. Similarly, Pereyra and Sanchez (2006) [12] also recorded the net reproductive rate (Ro) 48.92 individuals per female.

Intrinsic rate of increase (rm) of *T. absoluta* was 0.19 (female progeny/ female/day). The results of present study supported with the findings of Attwal *et al.* (2015) [2] who reported the intrinsic rate of increase of *T. absoluta* as rm = 0.17. Mean generation time (Tc) (days), corrected generation time (T) (days), finite rate of increase (λ) and weekly multiplication of population (λ^7) of *T. absoluta* were Tc= 30.16, T=28.94, λ= 1.20 and λ^7 =35.83, respectively (Table 2). Similar results were obtained by Ghorbani *et al.* (2016) [9] who reported that the finite rate of increase (λ) and mean generation time (Tc) of *T. absoluta* were recorded as 1.1710 ± 0.0068 (d^{-1}) and 27.21 ± 0.35 (days) on Mobil tomato variety, respectively. Cekin and Yasar (2015) [5] also reported that the net reproductive rate (Ro) was 64.6, 55.8, 47.5, and 35.8 female females^{-1} day^{-1} on Torry, Newton, Caracas and Simsek varieties, respectively. The intrinsic rate of increase (rm) was found as 0.17, 0.16, 0.15 and 0.15 females females^{-1} day^{-1} on Torry, Newton,

Caracas and Simsek tomato varieties, respectively. Turen and Yasar (2015) [23] reported that the net reproductive rate (R_0) was 13.39, 8.31, 8.25 and 4.98 females per female per generation; The intrinsic rate of increase (rm) was 0.08, 0.08 and 0.07, 0.05 females per female per day; and the mean generation time (T_0) was 29.60, 25.70, 29.00 and 28.70 days, on tomato varieties Alegria, Marabel, Marfona and Lady Olympia, respectively

Table 1: Age specific fecundity life table of South American tomato leaf miner, *T. absoluta* on tomato

Host	Age in days (X)	Number of female individuals in age class (nx)	Survival rate from birth (lx)	Fecundity at each stage (Fx)	Eggs produced per surviving individual at each stage (mx)	Net reproductive rate (lxmx)	lxmx. X
Tomato (Sweakar-448)	27	15	0.30	122	8.13	2.43	65.61
	28	15	0.30	252	16.80	5.04	141.12
	29	15	0.30	343	22.86	6.85	198.65
	30	14	0.28	425	30.35	8.49	254.7
	31	14	0.28	506	36.14	10.11	313.41
	32	12	0.24	139	11.58	2.77	88.64
	33	12	0.24	129	10.75	2.58	85.14
	34	11	0.22	96	8.72	1.91	64.94
Total				2012	145.33	40.18	1212.21

Table 2: Age specific fecundity life table parameters of South American tomato leaf miner, *T. absoluta* on tomato

S No.	Parameter	Host-Tomato hybrid (Sweakar-448)
1.	Net reproductive rate (R_o)	40.18
2.	Mean generation time ($T_c=\sum lxmx.X/R_o$)	30.16
3.	$\log_e R_o$	5.50
4.	Intrinsic rate of natural increase (r_c)	0.18
5.	Intrinsic rate of increase (rm)	0.19
6.	Corrected Generation Time ($T= \log_e R_o/ rm$)	28.94
7.	Finite rate of increase (λ = Anti $\log_e r_m$)	1.20
8.	Weekly multiplication of population (λ^7)	35.83

4. Conclusions

The net reproductive rate (R_0), intrinsic rate of increase (rm), mean generation time (Tc), corrected generation time (T), finite rate of increase (λ) and weekly multiplication of population (λ^7) of *T. absoluta* were $R_0 = 40.18$ individuals per female, 0.19 (female progeny/female/day), Tc= 30.16 days, T=28.94 days, λ= 1.20 and λ^7 =35.83, respectively.

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