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Biological Characteristics and Accumulated Thermal Heat Units of Tomato Borer, *Tuta Absoluta* (Meyrick)

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ABSTRACT

The present experiments were conducted under laboratory conditions to study the effect of different constant temperatures (25, 30 and 35^{0}C) on the development and mortality of the different stages of tomato leafminer, *Tuta absoluta* (Meyrick) , and to determine the thermal units required for *T.absoluta* development in relation with degree-days (DD's). The incubation period lasted 5.0 ± 0.6, 4.0 ± 0.6 and 3 ± 0.6 days for eggs at constant temperatures 25, 30 and 35 ^{o}C, respectively. The duration of the larval stage was 18.1± 0.2, 12± 0.2 and 8.5± 0.2 days at 25, 30 and 35 ^{o}C, respectively. The pupal average durations were 8.5± 3.1, 5.8± 1.4 and 5.2 ± 1.4 days at 25, 30 and 35^{o}C, respectively. The total developmental periods from egg to adult emergence were 31.6 ±4.5, 21.9 ±1.8 and 16.7 ±1.2 days for 25,30 and 35 ^{o}C, respectively. These results proved that all the developmental periods decreased with increasing temperature. The thresholds of development (t_0) were 10.4, 16.3, 8.6 and 13.8 for eggs, larvae, pupae and all immature stages, respectively. The mean thermal constant required for development of *T. absoluta* eggs, larvae and pupal stages was 75.5 DD's, 160.8 and 182.3 degree-days, respectively

Keywords: *Tuta absoluta*, thermal units, degree-days, development .

INTRODUCTION

The tomato crop (*Lycopersicon esculentum*)(L,) is becoming one of the most vegetable crops grown for both local consumption and export ; it is an important source of vitamins . Tomatoes can make people healthier and also can decrease the risk of condition such as cancer, osteoporosis and cardiovascular disease (Debjit *et al* ,. 2012) .

Tuta absoluta (Meyrick) (Lepidoptera Gelechiidae) is a devastating pest of tomato (*L. esculentum*), commonly known as tomato leafminer also feeds on other host plants from Solanaceae family (Vargas, 1970). It was first recorded in Western Egypt in late 2009 (Temerak, 2011). Recently ,this leaf miner is considered to be a serious threat to tomato production in the Mediterranean region, The newly introduced pest might find the climate at the shores of the Mediterranean a perfect new home where it can breed 10-12 generations a year (Pereyra and Sanchez, 2006).

The thermal unit provides a valuable tool for insect pest control; in forecasting infestations monitoring and timing of insecticide applications (Zalom *et al*., 1982). From the practical aspect, accumulated thermal units have been used to predict the seasonal development and emergence of various insects (Farag *et al*., 2009 and Abolmaaty *et al*. (2010).

The present study aims to evaluate the effect of different constant temperatures on the development of *T. absoluta* and to determine the thermal units required for *T.absoluta* development in relation with degree-days (DD's).

MATERIALS AND METHODS

Eggs and larvae of *Tuta absoluta* were collected from the leaves of tomato plants and reared in the laboratory in jars (250 cc) which covered with pieces of thin mesh fixed in place with a rubber band; larvae were fed on leaves of the tomato until pupation. Pupae transferred to a larger container until adults were appeared. Moths were placed in pairs in plastic containers 15 cm high, with moist vermiculite covering the base, and fine gauze, held in place by a rubber band, over the top. They were supplied with a 20% honey solution in small covered plastic containers (pill boxes) with an extruding cotton dental wool wick (Roberts, 1979). After then, mating occured at 1-2 days after eclosion and lasts 20-50 minutes (Harakly and Farag, 1975). Moths begin egg-laying 1-5 days after mating (Rashid *et al*. 1971).

The newly laid eggs distributed in three jars, each jar put in an incubator. Every incubator had different temperature; the temperatures were 25, 30 and 35˚C. They reared by the method mentioned above. The biology of the pest in each temperature had studied.

The newly hatched larvae were maintained under laboratory conditions till adult emergence. The emerged adults were allowed to reproduce under the constant temperatures 25, 30 and 35°C. The resulted eggs were collected and each one incubated in the constant temperature. The incubation period was calculated at each temperature. The hatched larvae were reared at the same constant temperature till pupation, then adult emergence. The larval and pupal durations were calculated and adult longevity as well.

Linear regression method was applied to calculate the theoretical development threshold as follows: Where the reciprocal for duration time of each stage (y) in days, 1/y is multiplied by 100 plotted against temperature (t) in degree centigrade, so the value of the ordinate (100/y) represents the average percentage development made by the stage per day at a given temperature (Campbell *et al*., 1974). Theoretically the point where the velocity line crosses the temperature axis is the threshold development in degree centigrade (t_0). Thermal units (degree-days) required to complete development of each stage was determined according to (Campbell *et al*. 1974) and (Ramadan, 2008). The degree-days (DD's) were calculated from the following equation:

$$\mathbf{DD = d\,(t - t_0)}$$

Where:

DD: thermal units (day-degree)

d: the developmental duration of a given developmental stage at constant temperature (t)

t_0: threshold temp in degree centigrade.

RESULTS AND DISCUSSION

- **Effect of temperature on the development and mortality of the immature stages:**
- **On the developmental periods:**

The influence of different constant temperature on the duration of the developmental stages of *Tuta absoluta* as well as on the reproductive potential of the adult female was estimated.

The obtained results could be summarized as follows:

A - Egg stage:-

Data in Table (1) show that the incubation period was affected by temperature. The incubation periods were 5.0 ± 0.6, 4.0 ± 0.6 and 3.0 ± 0.6 days at constant temperature of 25, 30 and 35 ^{o}C, respectively. A negative relation seems to exist between temperature and incubation period. There were significant differences between the incubation periods at different constant temperatures. The longest incubation period (5.0 ± 0.6 days) was recorded at 25 ^{o}C and the shortest (3.0 ± 0.6 days) one was recorded at 35 ^{o}C.

The present study illustrated that, temperature of 30^{0}C was the suitable for egg hatching and duration (highest hatchability and relatively shorter incubation period. Similar trend was recorded by Mahdi *et al.* (2011), who found that, the longest incubation period of *T. absoluta* eggs was recorded at 15 ^{0}C and 21^{0}C and the shortest period at 30 ^{0}C. Also, Pires and Marques (2002) found that at temperatures of 24.5-31.2 degrees C the incubation period was 4.6±0.05. This was also true for other gelechiidid eggs (Abou Hatab, 2005). Who, found generally that, high temperature was the optimum for the egg development.

B - Larval stage:-

The mean duration of *T. absoluta* larval stage at different constant temperatures are presented in Table (1). The larval duration tended to be shorted with the corresponding raise of temperature. At a given temperature, the time needed for the developmental of the larval stage were 18.1± 0.2, 12± 0.2 and 8.5± 0.2 days at 25, 30 and 35 ^{o}C, respectively. Statistically, there are significant differences between the mean durations at the tested constant temperatures.

Concerning the effect of constant temperature on the development of larval stage of *T. absoluta*, the duration of the larval stage decreased up to 35 ^{0}C, and lasted an average of 12± 0.2 at 30 0C. Similar results were obtained by Bentancourt *et al*., (1996) and Andrew *et al.* (2013) who mentioned that, as temperature increased (23 °C and above) development time of *T. absoluta* larvae would appear to decrease. According to Neto *et al*. (1988), the larval period of *T. absoluta* lasted about 10.9 days at 27± 2 0C and 11.9±0.15 days at temperatures of 24.5-31.2 (Pires and Marques, 2002).

C - Pupal stage:-

The duration of the pupal stage of *T. absoluta* at different constant temperatures are presented in Table (1). It is clear that, within the range of the tested temperature, developmental time of the pupal stage decreased as the corresponding temperature increased. The average durations were 8.5± 3.1, 5.8± 1.4 and 5.2 ± 1.4 days at 25, 30 and 35oC, respectively. There was a significant difference between the mean of pupal duration at 25^{o}C and those reared at 30^{o}C or 35^{o}C.

The previous results supported the results of Bentancourt *et al*., (1996), who found that, the duration of the pupal stage decreased up to 35 ^{0}C. Also, similar results was obtained by Pires and Marques (2002), who reported that at temperatures of 24.5-31.2 pupal periods were 6.5±0.33 days.

D - Total developmental time:-

As shown in Table (1), the total developmental periods from egg to adult emergence were found to be significantly affected by the variation in temperatures. The longest time required for the insect to complete its developmental stages (31.6 ±4.5 days) was recorded at 25 ^{o}C, whereas the shortest period (16.7 ±1.2 days) was recorded at 35 ^{o}C.

In general there was a negative relation between temperature and the development cycle of *T. absoluta*. As temperature increase the developmental period decreased. Nearly the same trend was recorded by Mahdi *et al*., (2011), who found that, the longest developmental period from egg to adult was recorded at 15±1 ^{0}C, meanwhile, the shortest time observed at at 30±1 ^{0}C. Andrew *et al.* (2013) also, reported that the shorted period needed for the development was recorded at 25 °C, while the longest one 13 °C. Also, the total developmental period from egg to adult was 38.1 days, at 27±2 (Neto *et al*.,1988) and was 22.2±0.35 days, at temperatures of 24.5-31.2 ^{0}C (Pires and Marques, 2002). According to Aguiar (2011) ,the biological cycle is completed in 29-38 days, depending on environmental conditions.

Table (1). Mean periods of the different developmental stages (egg, larva and pupa) of *Tuta absoluta* and the survival or mortality percentages of each stage at different constant temperatures.

Temperature	Developmental periods			
C	Incubation period	Larvae	Pupae	Total developmental periods
25	5.0 ± 0.6 a	18.1± 0.2a	8.5± 3.1a	31.6 ±4.5
30	4.0 ± 0.6 ab	12.0± 0.2b	5.8± 1.4b	21.9 ±1.8
35	3.0 ± 0.6 b	8.5± 0.2c	5.2± 1.4b	16.7 ±1.2
LSD 5%	1.99	0.61	2.74	
1%	3.02	0.88	4.16	

On the mortality:

As shown in Table (2), the highest percentage of unhatched eggs (50%) was recorded at 35^{o}C followed by 37.5% at 25 ^{o}C, meanwhile, the lowest rate of mortality (25%) was recorded at 35 ^{o}C. Statistically, there are significant differences between the mortality percent recorded at 30°C and both 25 or 35°C.

In respect to the mortality percentages among larval stage was significantly higher at 25 °C (50%) than those reared at 30 (33.33%) or 35 °C (40%).

Table (2): Mortality percentages of the different immature stages of the tomato leafminer *Tuta absoluta*.

Temperature C	Mortality % Eggs	Larvae	Pupae	From egg to pupa
25	37.5% b	50.00	33.33% a	79.2
30	25.0% a	33.33	40.00% b	70.0
35	50.0% c	40.00	43.5. % b	83.1
LSD 5%	4.44		4.15	6.5
1%	6.26		6.29	8.4

As shown in Table (2),the lowest mortality percentage of the pupal stage (33.33%) was obtained at 25°C followed by a mortality rate of 40.0% at 30°C, the highest mortality rate (43.5%) was recorded at 35 °C.

According to Andrew *et al*. (2013) high mortality of larvae occurred under all temperatures tested. Also, in the present experiments high mortality of *T. absoluta* larvae was recorded. Also, Torres *et al*., (2001) reported that the viability of *T. absoluta* larvae was 49.0 ± 14.5.

Generally, the obtained results revealed that, *T. absoluta* exhibited high mortality in the pupal stage at 30 and 35C. According to (Bentancourt *et al*., (1996) pupal stage was affected at 35 degrees °C. At this temperature, the papal mortality and the rate of abnormal adults were the highest. Similar finding was obtained by Moreira *et al*., (2009), who reported that pupal mortality rates of reached to 50.68%.

- **Effect of temperature on the adult female stage:**

As shown in Table (3), adult longevity at each temperature was divided into pre-oviposition, oviposition and post-ovipostion periods. In general the adult longevity for *T.absoluta* decreased with temperature increased from 18.5 days at 25°C to 13 days at 35°C

The pre-oviposition period seems to be affected by temperatures. The longest pre- oviposition period (8.0± 0.5) was recorded at 25 °C, while, the shortest was recorded at 35 °C. While at 27±4 °C the pre-oviposition period lasted 2.3 days Neto *et al* .(1988).

Data in Table (3) indicated that the oviposition periods also varied according to the prevailing temperature. The oviposition periods were 4.0± 0.5, 3.5± 0.2 and 2.5± 0.2 days at 25, 30 and 35 °C, respectively. It is obvious that, oviposition period decreased with the increase of corresponding temperature. There are significant differences between the means of oviposition period at 35oC and the means at 25 and 30°C. Similar results were obtained by Neto *et al* .(1988), who found that the oviposition period lasted about 3.77 day at 27±4 °C. While at relatively low temperature lasted 5.5 and 8.5 days (Moreira *et al*., (2009).

The shortest post-oviposition period was recorded at 35 °C, while the longest was obtained at 25 °C. The analysis of variance revealed thr presence of significant differences between the post oviposition periods and the tested temperatures.

In general, as shown in Table (3), it is clear that, the pre –oviposition period needed more than 40% of the total life span duration. Adult reared at 35 °C survived about two third as adult reared at 25 °C.

The obtained data in Table (3) showed that, the average period of the adult female life span averaged 18.5± 0.8, 16.0± 1.2 and 13.0± 1.2 days at 25, 30 and 35 °C, respectively. There was a negative relationship between the female longevity of *T.absoluta* and all tested temperature degrees. Statistical analysis indicated that there are significant differences between the mean of female longevity at 25°C and corresponding ones at 30 and 35°C. According to Andrew, *et al* (2013) adult longevity was longest at 10 °C with moths living for 40 days and shortest at 19 °C where they survived for 16 days.

Table (3). Adult female longevity (pre- oviposition, oviposition and post- oviposition periods) of TLM, *Tuta absoluata* at different constant temperatures.

Temperature	Pre-oviposition period (days)	Oviposition period	Post oviposition period(days)	Longevity (days)
25	8.0± 0.5 a	4.0± 0.5 a	6.5± 0.2 a	18.5± 0.8 a
30	7.0± 0.5 a	3.5± 0.2 a	5.5± 0.2 ab	16.0± 1.2 b
35	6.0± 0.5 b	2.5± 0.2 b	4.5± 0.2 b	13.0± 1.2 c
LSD 5%	1.2	1.4	1.2	1.5
1%	3.02	2.14	2.3	2.6

II- Determination the thermal units required for *T.absoluta* development in relation with degree-days (DD's) :-

The aim of the present experiments is to study the relationship between temperature and speed of development, using thermal summation. The obtained data of this part of study are summarized as follows:-

- **The egg stage:**

The three observed values for egg rate of development at the temperature range from 25 to 35°C (Table, 4) , are remarkable good fit to the calculated temperature – velocity line for the embryonic development having the formula:: Y = -13.8 + 1.13X (Fig.1A). So, The calculated developmental threshold (t_0) for the embryonic development was 10.4 DD's (Table, 4).

Table (4) : Developmental rate (D.R.% .), developmental threshold (t_0) and thermal units (DDS) needed for the development of immature stages of the tomato leafminer, *Tuta absoluta* reared at different constant temperature(25, 30 and 35°C).

Immature Stages	T_0	Temperature (°C) ٢٥ D.R. %	٢٥ Thermal units	٣٠ D.R. %	٣٠ Thermal units	٣٥ D.R. %	٣٥ Thermal units	Mean Thermal unit
Egg	١٠.٤	٢٠.٠	٧٣.٥	٢٥.٠	78.8	٣٣.٣٠	٧٤.١	75.5
Larva	١٦.٣	٥.٥٢	157.5	8.3	165.8	١١.٧٦	159.0	160.8
Pupa	8.6	11.7	285.6	17.2	124.1	١٩.٢٠	١٣٧.٣	182.3
Total immature stages	١٣.٨	٣.١٦	353.6	٤.٥٦	245.1	٥.٩٨	186.9	261.9

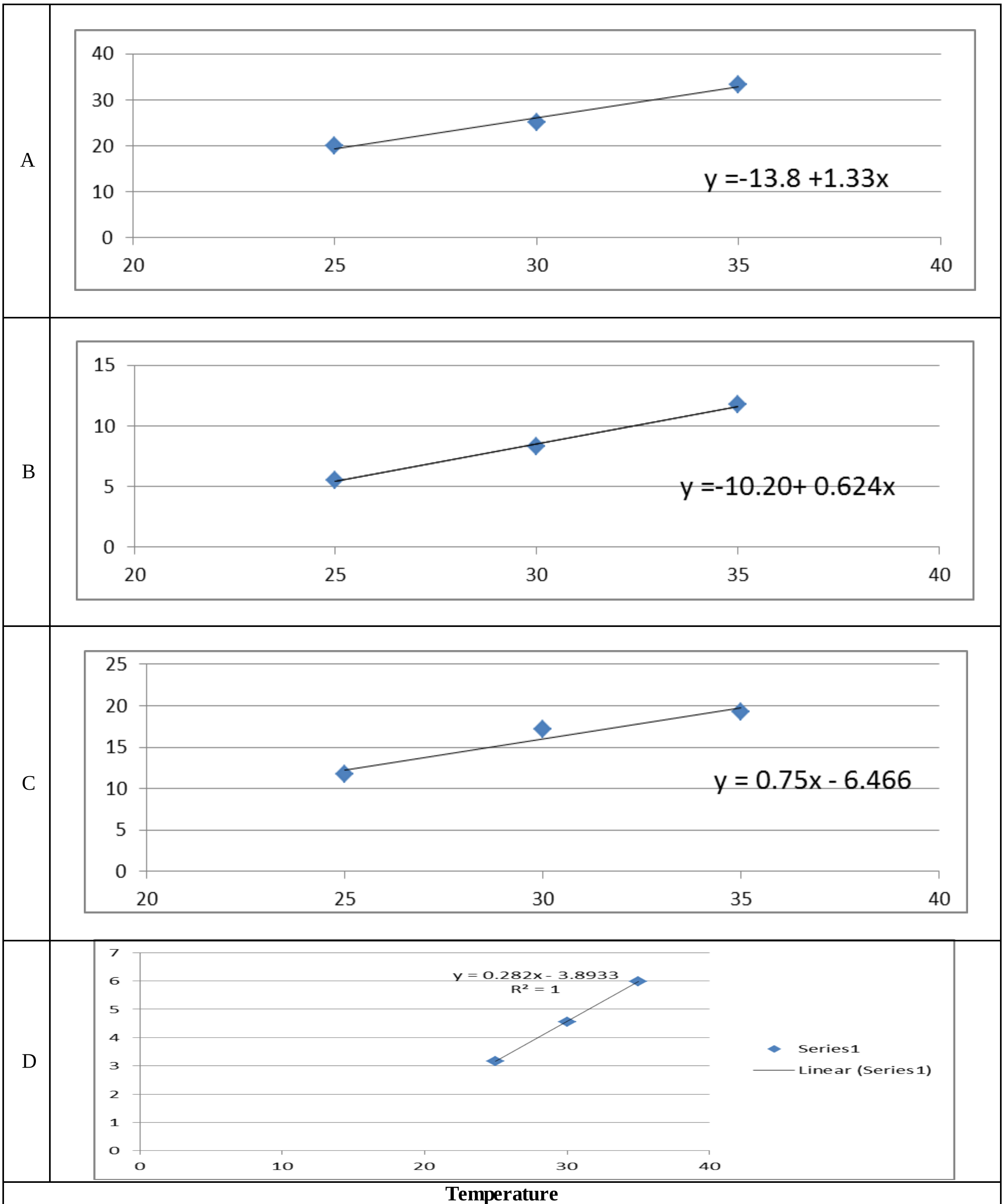

Fig. (1). The relationship between the developmental rate of *Tuta absoluta* immature stages (eggs (A), larvae (B), pupae (C) and total developmental time (D)) and different constant temperatures (25, 30 and 35C).

The average thermal units in degree-days (DD's) required for the completion of development of egg stage are presented in Table (4). The obtained data indicated that thermal units in degree-days were 73.5, 78.8 and 74.1 DD's at 25, 30 and 35 ^{o}C, respectively, with an average of 75.6 DD's. These results illustrated that the rate of development was slower at 25^{o}C than at 30 ^{o}C and 35^{o}C. Thus, it is clear that the constant temperature from 30 ^{o}C to 35^{o}C is the optimum zone of effective temperature for the development of *T. absoluta*.

2-The larval stage:

The calculated developmental thresholds (t_0) for larval stage of *T.absoluta* were determined as in Figure (1A), where its value reached 16.3^{o}C. The relation between the developmental rate of *T.absoluta* and temperature degrees could be represented by the following formula (Y = - 10.20 + 0.624 X).

By using these values as a base temperature, The mean values of thermal units required for larval development were 157.5, 165.8 and 158.95 degree-days at 25, 30 and 35^{o}C, respectively (Table, 4). According to the thermal summation equation (K = y (T – 16.3) the average of total thermal units was 160.73 degree-days.

- **The pupal stage:**

Data presented in Table were also used to estimate the developmental threshold (t_0) for *T. absoluta* pupae as illustrated graphically in Fig. (1 B), was found to be 8.6^{o}C (according to the calculated temperature-velocity line, formula, Y = -6.466 + 0.75x).

In respect to the pupal stage, the thermal units are 285.6, 124.1 and 137.3 degree-days at 25, 30 and 35 ^{o}C, respectively. According to the thermal summation equation K = y (T – 8.6), the average of total thermal units was 182.3 degree-days.

- **All immature stages:**

The relation between the developmental rate of *T. absoluta* immature stages and temperature degrees could be represented by the following formula (Y = - 3.8933 + 0.282 X). The calculated developmental threshold (t_0) was about 13.81 ^{o}C. By using this value as a base temperature, the mean values of thermal units required for larval development were 353.60, 245.06 and 186.87degree-days at 25, 30 and 35^{o}C, respectively (Table, 4). According to the thermal summation equation the average of total thermal units was 261.84 degree-days.

According to (Merrill *et al*. 2008 and Abolmaaty *et al*., 2010), temperatures has a direct effect on the insect physiology. In the present study the lower threshold temperature for the embryonic, larval and pupal development was 10.38, 16.3^{o}C and 8.6^{o}C, respectively. These results disagree with those obtained by Barrientos *et al.,* (1998). Who reported that the lower threshold temperature for the egg, larva, and pupal stages averaged 6.9 ^{o}C, 7.6 ^{o}C and 9.2 ^{o}C , respectively. These differences may be attributed to *T. absoluta* strains.

The mean thermal constant required for development of *T. absoluta* eggs, larvae and pupal stages was 75.5 DD's, 160.8 and 182.3 degree-days, respectively. While, Barrientos *et al*., (1998) found that the thermal constant for the development of egg, larva and pupa was 103.8, 238.5 and 117.3 degrees D; all of these add 459.6 degrees D. These differences may attributed to the strain differences.

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الخصائص البيولوجية و الاحتياجات الحرارية لحشرة حفار الطماطم ، توتا أبسلوتا

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تهدف الدراسة الحالية لمعرفة تأثير درجات الحرارة الثابتة (٢٥ ،٣٠ ، ٣٥ ºم) علي النمو و نسب الموت في الاطوار المختلفة لحفار اوراق الطماطم و كذلك تقدير الاحتياجات الحرارية لنمو الحشرة ، تحت الظروف المعملية . و قد أوضحت الدراسة أن فترة حضانة البيض بلغت ٥.٠±٠.٦ ، ٤.٠±٠.٦ ، ٣.٠±٠.٦ أيام علي درجة حرارة ٢٥ ، ٣٠ ، ٣٥ ºم علي التوالي . و كانت فترة نمو الطور اليرقي ١٨.١±٠.٢ ، ١٢±٠.٢ ، ٨.٥±٠.٢ أيام علي درجة حرارة ٢٥ ، ٣٠ ، ٣٥ ºم علي التوالي . كما بلغت متوسط فترة طور العذاري ٨.٥±٣.١ ، ٥.٨±١.٤ ، ٥.٢±١.٤ أيام علي درجة حرارة ٢٥ ، ٣٠ ، ٣٥ ºم علي التوالي . و كان إجمالي فترات نمو الأطوار الغير كامله ٣١.٦±٤.٥ ، ٢١.٩±٤.٨ ، ١٦.٧±١.٢ أيام علي درجة حرارة ٢٥ ، ٣٠ ، ٣٥ ºم علي التوالي . و قد أو ضحت هذة الدراسة أن فترات النمو تقل مع زيادة درجات الحرارة . و قد بلغت عتبة النمو ١٠.٤ ، ١٦.٣ ، ٨.٦ ، ١٣.٨ لكل من طور البيضة و اليرقة و العذراء و جميع الأطوار الغير كاملة علي التوالي . كما بلغ متوسط الاحتياجات الحرارية لنمو الحشرة لكل من البيض و اليرقات و العذاري ٧٥.٥ ، ١٦٠.٨ ، ١٨٢.٣ DD,s علي التوالي .