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DEVELOPMENTAL THRESHOLDS AND THERMAL REQUIREMENTS NEEDED FOR THE COTTON PINK BOLLWORM *PECTINOPHORA GOSSYPIELLA* (SAUNDERS)

[183]

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ABSTRACT

The present study was conducted on the cotton pink bollworm, *Pectinophora gossypiella* (Saunders.) (Lepidoptera: Gelechiidae) the most devastative insect pest to cotton cultivations in Egypt. It causes great damage and loss in the cotton yield. All experiments were carried out in the laboratory of the environmental study, Department of Plant Protection, Faculty of Agric., Ain Shams Univ. aiming to estimate some biological parameters of *P. gossypiella* reared on artificial diet at four constant temperatures 18, 20, 25, 30ºC with 65±5% RH, then determine threshold of development and thermal constant for each of the developmental stages and complete generation. Obtained results demonstrated that the duration of each developmental stage of *P. gossypiella* highly affected by the change of temperature. The incubation period of eggs greatly varied at different temperature, these periods were 10.86, 10.29, 6.00 and 4.00 days at 18, 20, 25 and 30ºC, respectively. Threshold of development for *P. gossypiella* egg stage was 12.1ºC. The mean of duration for *P. gossypiella* larvae, pupae were 30.40, 14.10 days and the durations for male, female and generation were 24.72, 26.99 and 57.95 days, respectively. The longest duration of larvae, pupae, male and female moths were 47.61, 20.13, 33.59 and 33.68 days recorded at 18ºC while the shortest durations were 16.60, 7.40, 13.75 and 14.64 days recorded at 30ºC for larvae, pupae, male and female moths, respectively. The threshold of development for *P. gossypiella* larval, pupal, male, female stages was 11.6, 12.1, 9.8, 9.5ºC, respectively. The threshold of development for *P. gossypiella* generation was 11.7ºC. Based on the estimated threshold of development and duration of each developmental stage at the respective rearing temperature, the average of thermal constant was estimated as 73.59 for egg stage, 298.76 for larvae, 124.98 for pupae, 299.49 for adult male, 338.96 for adult female and 567.8 DDs for *P. gossypiella* generation.

Keywords: *Pectinophora gossypiella*; Pink bollworm; Developmental threshold; Thermal constant

INTRODUCTION

Cotton is an important commercial crop grown for fiber, fuel and edible oil under different agro-climatic conditions. The cultivated area across the country was 217,000 feddans in 2017 produced 2,580.00 Tons **(Central Agency for Public Mobilization and Statistics Egypt, 2017).** There are many pests affecting cotton production negatively; one of them is the cotton pink bollworm. (PBW), *Pectinophora gossypiella* (Saunders) is the most serious pest of cotton crop as larvae attack the fruitful part of the plant. Larvae are active after hatching but they will die if they didn't find a fruiting body within 1 or 2 days **(Fenton and Owen, 1953).** The incidence of *P. gossypiella* in several hotspots caused serious boll damage **(Naik et al 2018).** The early predicting of the pest is very essential to aid farmers to take actions for restricting the dangerous infestation. Although the pest can increase or decrease its body temperature from ambient temperature, in general, there is a reasonable range of temperatures make the pest rate of development predictable by using heat accumulations **(Ray, 2001)**. The application of thermal requirements is an important way to predict seasonal activity of the

pest, also it is very important for the agriculture integrated pest management (IPM) programs. The present study aimed to estimate the time needed for total developmental stages of PBW to complete one generation and for estimating the threshold of development for its different developmental stages.

MATERIALS AND METHODS

1. Mass rearing of PBW

Eggs of *Pectinophora gossypiella* were obtained from the Department of Bollworms Research, Plant Protection Research Institute, Dokki, Giza, Egypt. The newly hatched larvae were reared on artificial diet under laboratory condition for two generations in the Laboratory of Ecological Studies, Department of Plant Protection, Faculty of Agriculture, Ain Shams University, during 2018.

2. Experimental design

Four incubators were adjusted at four constant temperatures of 18, 20, 25 and 30ºC. The stages from egg to adult were kept under the previous four constant temperatures and 65±5% R.H. for determining the developmental rate for each stage.

2.1. Egg stage

Five couples (♂+♀) of moths were kept under lanterns, the lantern is a cage for mating moths which is made of glass and has two openings, one at the top and the other at its base, both openings are covered with gauze and tide with rubber band, the base opening was set in petri dish (10cm. diameter). Eggs were collected in the same day of laying, transferred to glass vials (2.0×7.5 cm) and incubated at the required temperature and relative humidity. Five replicates of eggs were used for each tested temperature each one contains 20 eggs. Observations were done every day to calculate embryonic developmental rates and incubation periods.

2.2. Larval stage

To follow the developmental rate of *P. gossypiella* larvae, newly hatched larvae were transferred in a separate glass tube (2.5X7.5 cm) covered with absorbent cotton and contained fresh piece of artificial diet. Each constant temperature had 100 larvae. The larvae were left in the vials until pupation. Daily observations were made and the pupated larvae were counted and calculate the percentage of pupation. Durations and larval developmental rates were estimated and recorded.

2.3. Pupal stage

Newly formed pupae were collected on the same day of the pupation, 80 pupae were used for each temperature then placed individually in a glass tube (2.5× 7.5cm) and plugged tightly with a piece of cotton. Duration of pupal stage was recorded until adult emergence at each temperature.

2.4. Adult stage

Newly emerged moths were sexed and transferred on the same day of emergence to lanterns and kept in the same conditions of temperature and R.H%. 25 replicates were used for each temperature, each replicate contains a single female + a single male. Daily observations were done for calculating adult longevity. Deposited eggs were collected, counted and incubated at the same temperatures in order to calculate the fecundity and

3. Diet preparation:

The used artificial diet was prepared according to **Abdel-Hafez et al (1982).**

The diet was prepared as follows: 860g dry kidney beans, 48g agar up to 600ml of tape water, 128g of medical dried yeast, 5.5g of sorbic acid, 11g of ascorbic acid 5.5g of methyl hydroxyl benzoate and 17ml. of formaldehyde 40%. To prepare the agar solution, 48g of agar were gently added to 600ml of tape water and stirred for 5 min. in water bath. All contents of the medium were mixed together in a blender and left for five hours to allow cooling.

4. Linear regression method

The theoretical development threshold values were determined as the following:

1- The points obtained when time (t) in days is plotted against the temperature (T) in degree centigrade (ºC). The relationship is hyperbolic as normally observed in many insect species **(Bean, 1961 and Hafez, 1961)**.
2- The point when the equal for time (1/t) in days plotted against temperature (T) in degree centigrade (ºC), each of the equal is multiplied by 100, so the values on the ordinate (100/t) represent the rate of the average percentage de-

velopment which made by the stage per day at the given temperature. Therefore, the distribution of the points indicates the temperature velocity curve **(Davidson, 1944).** Values of the average percentage of development in one day presented within an effective normal zone of development are fitted to straight line by the method of least square (Regression line). Theoretically, the threshold of development is the point which the velocity line crosses the temperature axis. The upper threshold limit was estimated by using the linear regression equation; Y= a + bx, as y is the rate of development at temperature x, values a and b are the regression constant values. In this equation x is the value of the threshold when Y= zero **(Park, 1988)**. The thermal units (TU) required for the development of each stage were calculated according to the equation of **Madubunyi and Koehler (1974)**; TU =T ($t-t_o$), where T = the developmental period in days at temperature t, t = the exposure temperature (ºC) and t_o = the temperature threshold.

RESULTS AND DISCUSSION

1. The developmental parameters of pink bollworm *Pectinophora gossypiella* as explained by thermal accumulated units.

1. Egg stage

Data in **Tables (1 & 2)** showed the required durations to complete the embryonic development (incubation period). The mean of incubation periods varied greatly on different constant temperatures where "F" value =116.6, Sig. at 0.001 and L.S.D. = 0.8 day. The incubation periods were 10.86, 10.29, 6.00 and 4.00 days at 18, 20, 25, and 30ºC. The longest mean of incubation period was 10.86 days at 18ºC; while the shortest one was 4 days at 30ºC. As well as the threshold of eggs (embryonic development) was 12.1ºC.

As shown in **Table (2)** the rate of development was the lowest at 18ºC than at the other degrees, while the constant temperature 30ºC has the highest rate of development. The estimated thermal units required for eggs development based on the estimated threshold of development of the egg stage of *P. gossypiella* incubated at the four tested constant temperatures 18, 20, 25 and 30ºC were 64.07, 81.29, 77.40 and 71.60 DDs, respectively. The mean of total thermal units was 73.59 DDs.

The obtained results were closely related to **El-Sayed and Rahman (1960)** who recorded 7.37 days for the incubation period of *P. gossypiella* at 25ºC; **Gergis et al (1990)** mentioned that the average of thermal units needed for *P. gossypiella* eggs was71.94 DDs. **Cacayorin et al (1992)** indicated that the incubation period of *P. gossypiella* was 6.7 days at 25ºC. The present results also nearly similar to those found by **Vennila et al (2007)** who reported that the incubation period for *P. gossypiella* eggs was 6 days at 27ºC; **Dharajothi *et al*. (2016)** also found that the incubation period of *P. gossypiella* eggs was 4.8 days when adult reared as larvae on artificial medium at 28ºC.

2. Larval stage

Tables (1 & 2) showed that the mean of *P. gossypiella* larval durations at the four tested constant temperatures 18, 20, 25 and 30ºC were 47.61, 36.61, 20.70 and 16.60 days, respectively. Statistically, there were significant differences among these degrees. ("F" value =14419.9, Sig. at 0.001 and L.S.D. = 0.3 day). This table clearly indicates that the developmental rates increased as the temperatures increased.

The duration of larval stage at the four constant temperatures was used for estimating threshold of development for the larval stage. Results indicated that this value was 11.6ºC **(Table 2 and Fig. 3)**.

The shortest rate of development of *P. gossypiella* larvae was recorded at 18ºC as compared to other degrees **(Table 2)**. The constant temperature 30ºC showed the highest rate of development. The mean of total thermal units needed for larvae to complete their development was 298.76 DDs. The estimated thermal requirements for larval stage at the four constant temperatures 18, 20, 25, 30ºC were 304.70, 307.52, 277.38, and 305.44 DDs.

Obtained results were in harmony with those found by **Muralimohan et al (2009)** who observed the shortest larval period of 21.34 days on two phase diet (cottonseed flour + okra) at 27ºC and were in close with **Yones et al (2011)** who mentioned that the lower threshold of development for *P. gossypiella* larvae was14.07ºC, also were in agreement with **Shah et al (2013)** who recorded 9 days at 35ºC and 13 days at 27ºC. The present results also nearly similar to **Dharajothi et al (2016)** who reported that the larval duration of *P. gossypiella* was 25.10 days on artificial medium at 28ºC.

Table 1. Duration of different developmental stages (in days) for *Pectinophora gossypiella* reared on artificial diet at different constant temperatures (2018)

Temp. / Stage	18 (°C)	20(°C)	25(°C)	30(°C)	Average	F	L.S.D (day)
Eggs	10.86±0.12	10.29±0.14	6.00±0.070	04.00±0.04	7.800	116.6	0.8
Larvae	47.61±0.08	36.61±0.06	20.70±0.02	16.60±0.03	30.40	14419.9	0.3
Pupae	20.13±0.40	19.20±0.05	09.85±0.08	07.40±0.15	14.10	1270.1	0.5
Male	33.59±0.30	27.72±0.09	23.82±0.02	13.75±0.24	24.72	114.0	4.0
Female	33.68±0.41	31.00±0.64	28.64±0.72	14.64±0.12	26.99	27.0	2.0
Generation	86.39	72.85	41.07	31.48	57.95		

3. Pupal stage

Data in **Tables (1, 2)** showed that the pupal periods decreased as temperature increased. The average durations were 20.13, 19.2, 9.85 and 7.40 days at 18, 20, 25 and 30ºC, respectively with an average of 14.1 days. Analysis of variance showed significant differences ("F" value =1270.112, Sig. at 0.001 and L.S.D. = 0.5 days).

As shown in **Fig. (4)** the estimated developmental threshold for *P. gossypiella* pupal stage was12.1ºC.

Rate of development was increased gradually as the temperature increased from 18 to 30ºC. The lowest rate % occurred at 18ºC (4.97) followed by 20ºC (5.21); while the highest rate occurred at 30ºC (13.51) **(Tables 1 & 2)**.

Results were in agreement with **Muralimohan et al (2009)** who found that the pupal duration of *P. gossypiella* was 7.9 days at 27ºC. Results of **Dharajothi et al (2016)** were also in the same trend.

4. Adult Longevity

Longevity of *P. gossypiella* male and female was represented from emergence of adults from pupae until death. Results of statistical analysis showed that there were highly significant differences among the four constant temperatures on means of longevity of both sexes where "F" =114.0, Sig. at 0.001 and L.S.D. = 4 days for males and these values were "F" = 27.012, Sig. at 0.001 and L.S.D. = 2 days for females **(Tables 1, 2)**.

The mean of male longevity was decreased as temperature increased. Mean of longevity was 33.59, 27.72, 23.82 and 13.75 days, at 18, 20, 25 and 30ºC, respectively. The threshold of development was calculated as 9.8ºC **(Fig. 5)**. The thermal unit needed for adult males were 275.44, 282.74, 362.06 and 277.75DDs at 18, 20, 25 and 30ºC, respectively **(Tables 1 & 2).**

Females lived longer than males at the four tested temperatures. Results in **Tables (1, 2)** showed that mean of female longevity was decreased as temperature increased. Means of longevity were 33.68, 31.00, 28.64, 14.64 days at 18, 20, 25 and 30ºC, respectively. The threshold of development as indicated in **Fig. (6)** was 9.5ºC.

The thermal units required for adult female were 286.28, 325.50, 443.92 and 300.12 DDs 18, 20, 25 and 30ºC, respectively with a mean 338.96 DDs.

Results were in close harmony with **Adkisson (1961)** who reported that the average duration of *P. gossypiella* adult life span for females reared as larvae from the various diets ranged from 15.4 to17.2 days at 26ºC. Results were also nearly similar to **Muralimohan *et al*. (2009)** who observed adult male and female longevity of *P. gossypiella* which were 21.05 and 24.65 days at 27ºC, respectively; **Shah et al (2013)** who reported the life span of male and female were 10 and 12 days at 35ºC, 18 and 25 days at 27ºC, respectively; **Zinzuvadiya et al (2017)** who observed that female and male longevity ranged from 5 to 11 and 9 to 16 days for female and male moths at 28ºC, respectively.

Table 2. Thermal requirements needed for development of different stages of *Pectinophora gossypiella* reared on artificial diet at different constant temperatures (2018)

Temp. / Stage	18 (°C)			20 (°C)			25 (°C)			30 (°C)			Average of thermal constant
	Rate of Development (%)	Threshold of development (°C)	Thermal constant (DDs)	Rate of Development (%)	Threshold of development (°C)	Thermal constant (DDs)	Rate of Development (%)	Threshold of development (°C)	Thermal constant (DDs)	Rate of Development (%)	Threshold of development (°C)	Thermal constant (DDs)	
Eggs	9.21	12.1	64.07	9.72	12.1	81.29	16.67	12.1	77.4	25	12.1	71.6	73.59
Larvae	2.1	11.6	304.7	2.73	11.6	307.52	4.83	11.6	277.38	6.02	11.6	305.44	298.76
Pupae	4.97	12.1	118.97	5.21	12.1	135.74	10.15	12.1	118.89	13.51	12.1	126.32	124.98
Male	2.98	9.8	275.44	3.61	9.8	282.74	4.2	9.8	362.06	7.27	9.8	277.75	299.49
Female	2.97	9.5	286.28	3.23	9.5	325.5	3.49	9.5	443.92	6.83	9.5	300.12	338.96
Generation	1.16	11.7	544.26	1.37	11.7	604.66	2.43	11.7	546.23	3.18	11.7	576.08	567.8

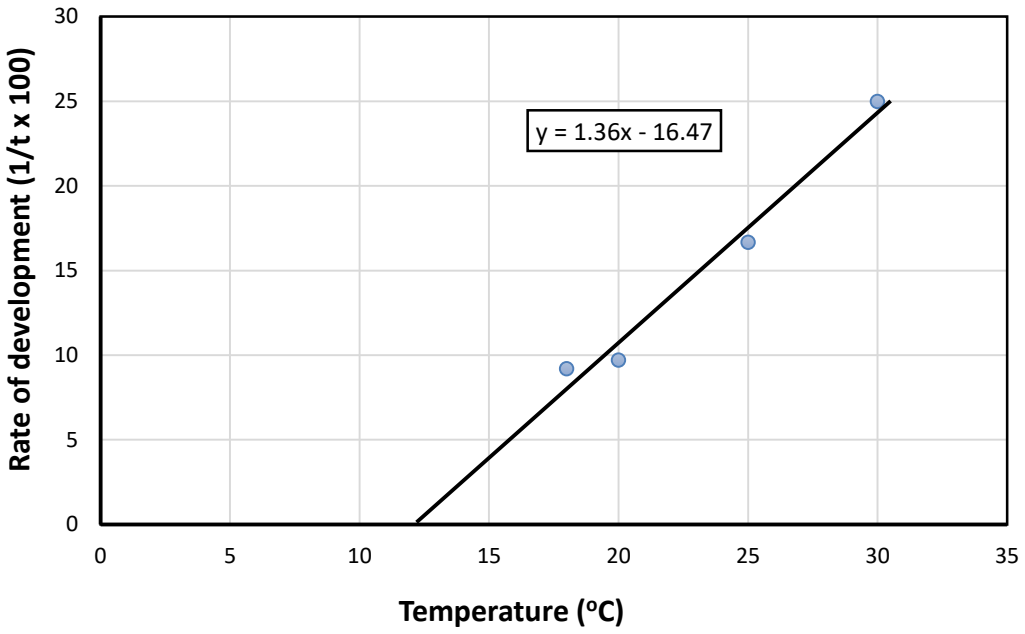

Fig. 1. The regression line between developmental rates of the egg stage of *Pectinophora gossypiella* and temperature

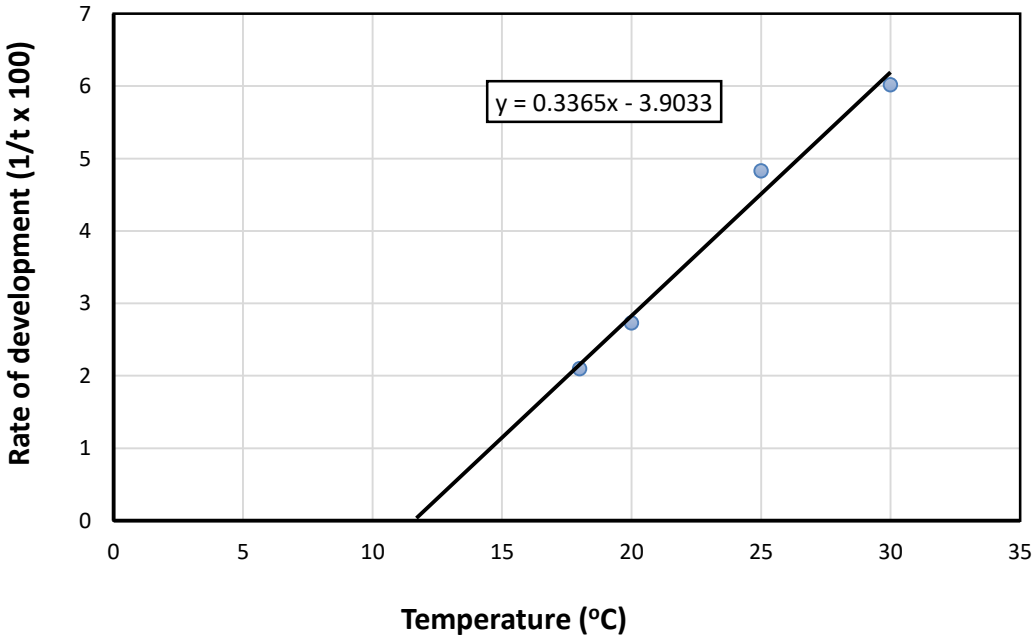

Fig. 2. The regression line between developmental rates of the larval stage of *Pectinophora gossypiella* and temperature.

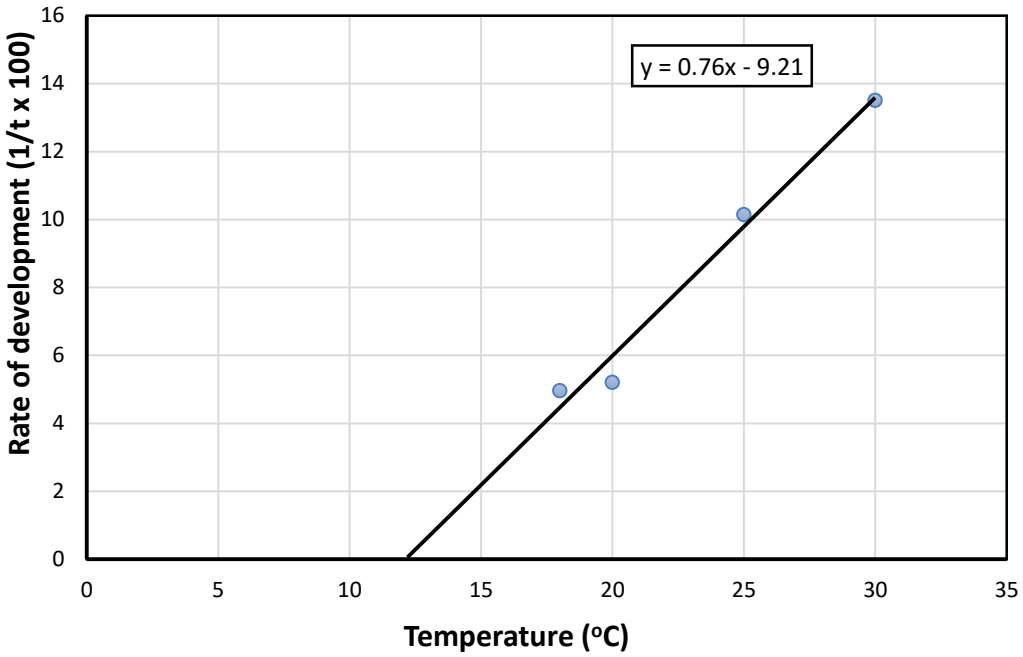

Fig. 3. The regression line between developmental rates of the pupal stage of *Pectinophora gossypiella* and temperature

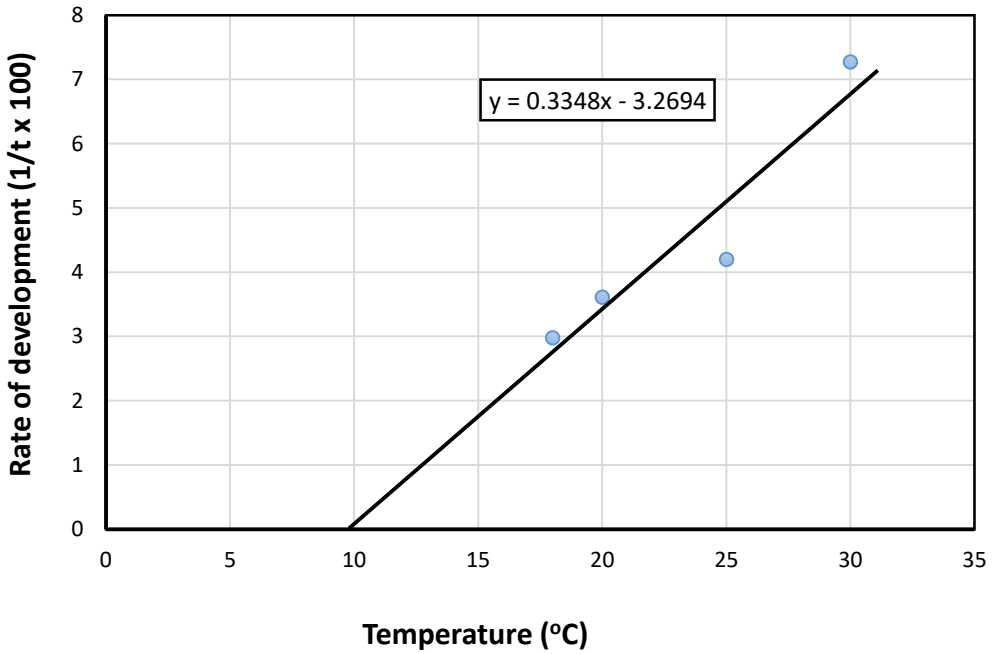

Fig. 4. The regression line of male longevity of *Pectinophora gossypiella* at four constant temperatures.

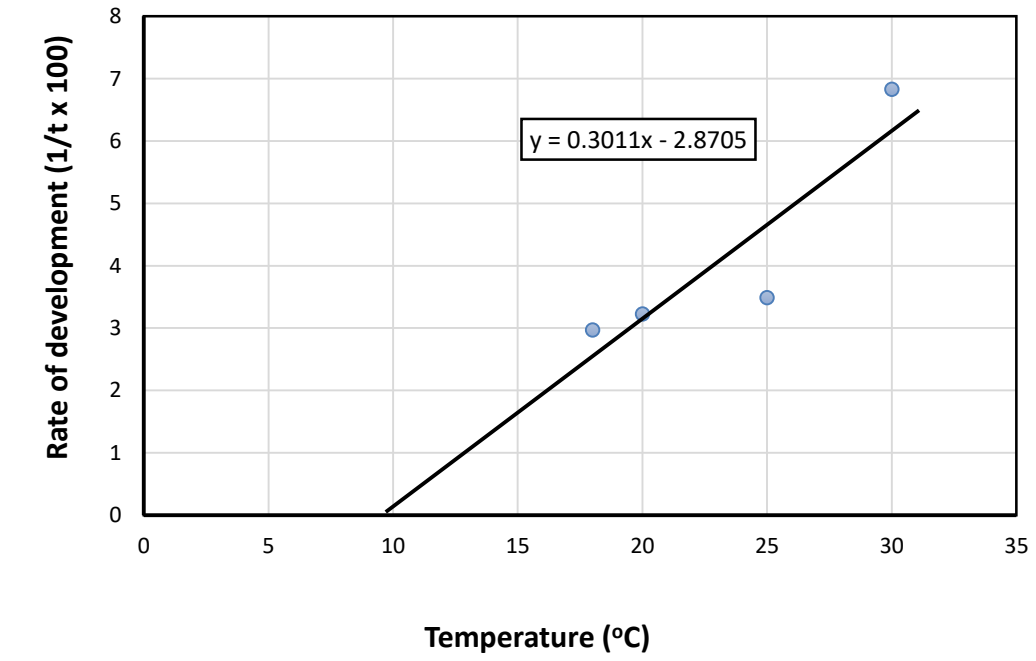

Fig. 5. The regression line of female longevity of *P. gossypiella* at four constant temperatures

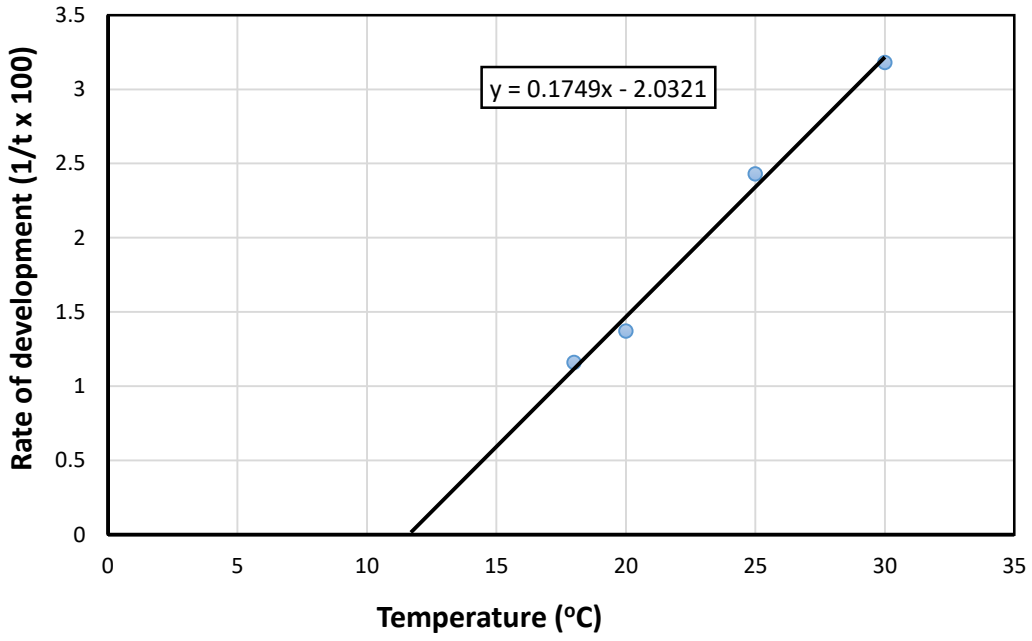

Fig. 6. Regression line of *Pectinophora gossypiella* generation at different temperatures.

5. Duration of *Pectinophora gossypiella* generation

Data in **Table (1)** showed the duration of *P. gossypiella* generation at four constant temperatures where the shortest duration of generation was occurred at 30ºC being 31.48 day, while the longest one was occurred at 18ºC being 86.39 days. The threshold of development was 12.29ºC **(Table 2 and Fig. 6).**

The thermal heat units required for the development of generation were 544.26, 604.66, 546.23 and 576.08 DDs at 18, 20, 25 and 30ºC, respectively with average of 567.81 DDs.

Results were nearly similar to **Gergis et al (1990)** who reported that the threshold of development for *P. gossypiella* generation was 12.7ºC. The results were also in harmony with **El-Saadany et al (2003)** who mentioned that the threshold temperature for *P. gossypiella* generation was 11.9ºC; **Yones et al (2011)** found that the lower threshold of development for *P. gossypiella* to complete the generation was 12.03ºC.

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الحدود الحرجه للنمو والاحتياجات الحرارية اللازمه لتطور دودة اللوز القرنفلية *Pectinophora gossypiella* (Saunders)

[183]

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الموجـــــز

أجريت الدراسة الحالية على حشرة دودة اللوز القرنفلية *Pectinophora gossypiella* (Saunders) والتى تعد أكثر الآفات الحشرية تدميرا لزراعات القطن في مصر، حيث أنها تسبب أضراراً شديدة وفقداً كبيراً في محصول القطن. وقد أجريت جميع التجارب في معمل الدراسات البيئية – قسم وقاية النبات – كلية الزراعة – جامعة عين شمس.

استهدفت الدراسة تقدير الاحتياجات الحرارية لأطوار الحشرة المختلفة وقد تم تربية الحشرة على بيئة غذائية صناعية على أربع درجات حرارة ثابتة هى 18، 20 ، 25، 30 درجة مئوية و رطوبة نسبية مقدارها 65±5% وقد تم تحديد الحد الحرج للنمو والتطور (صفر النمو) وأيضاً الثابت الحراري لكل طور من أطوار النمو وأيضا الاحتياجات الحرارية (الثابت الحراري) اللازمة لاكتمال الجيل. أظهرت النتائج المتحصل عليها أن مدة كل مرحلة من مراحل تطور الحشرة تتأثر بشدة بتغير درجة الحرارة وقد تباينت فترة حضانة البيض باختلاف درجات الحرارة، حيث كانت 10.86، 10.29، 6.00، 4.00 يوماً على التوالى عند التربية على درجات حرارة 18 و 20 و 25 و30 درجة مئوية على التوالى، وكان الحد الحرج لنمو وتطور البيض هو 12.1 درجة مئوية وكان متوسط الفترة اللازمة لتطور كلٍ من اليرقات والعذارى والذكور والإناث والجيل كاملاً هى 30.40، 14.10، 24.72، 26.99، 57.95 يوماً على التوالى.

وقد سجلت أطول فترة لنمو الأطوار المختلفة على درجة حرارة 18.0 درجة مئوية حيث كانت 47.61، 20.13، 33.59، 33.68 يوماً لكل من اليرقات، العذارى، ذكور الفراشات، وإناث الفراشات على التوالى بينما كانت أقصر فترة لتطور نفس الأطوارهى 16.60، 7.40، 13.75، 14.64 يوماً على التوالى على درجة حرارة 30 درجة مئوية. قدر الحد الحرج للنمو والتطور لكل من الطور اليرقى، العذارى، ذكور الفراشات، إناث الفراشات، والجيل كاملاً بـ 11.6 ، 12.1، 9.8 ، 9.5، 11.7 درجة مئوية على التوالي.

اعتمادا على قيمة الحد الحرج للنمو والتطور والفترة الزمنية اللازمة للتطور عند كل درجة تم تقدير الاحتياجات الحرارية (الثابت الحرارى) لكلٍ من البيض، الطور اليرقى، العذارى، الذكور، الإناث، الجيل كاملاً بـ 73.59، 298.76، 124.98، 299.49، 338.96، 567.80 وحدة حرارية (DDs).

الكلمات الدالة: دودة اللوز القرنفلية، الحد الحرج للنمو، الثابت الحراري

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