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Heat Requirements for the Development of the Black cutworm, *Agrotis ipsilon* (Hüfnagel) (Noctuidae: Lepidoptera)

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ABSTRACT

The present investigation aimed to study the effect of three constant temperatures (20, 25, and 30°C) on the development of the black cutworm, *Agrotis ipsilon* (Hüfnagel). The incubation period, larval duration, pupal duration, pre-oviposition period and duration of generation were estimated. The time required for development was decreased as the temperature increased from 20 to30 °C. The lower threshold temperatures (t_0) was 11.49°C for eggs, 10.63 °C for larvae, 9.83 °C for pupae, 11.06 °C for pre-oviposition period and 10.53 °C for generation. The average thermal requirements needed for completing the development were 51.3, 303.5, 183.5, 38.1 and 575.3 degree-days for eggs, larvae, pupae, pre-oviposition period and generation, respectively.

Key words: *Agrotis ipsilon* – Heat Requirements – Degree Days **-** Lower threshold (t_0**)** - Prediction.

INTRODUCTION

The Black cutworm, *A. ipsilon*, is one of the most important and abundant species of noctuidae in Egypt. It has become widely spread in recent years and its various ravages against field crops have been steadily increasing. It causes considerable damage to many of the more important field crops and vegetables.

The influence of temperature in determining the development of insect populations is well established (Davidson, 1944 and Ives, 1973); since the temperature is considered an important environmental factor that affects the rate of development of insects. There is a lower threshold temperature for each insect. No development occurs when temperature is below that level. Insects also have an optimum temperature range in which they will develop rapidly. Then, there is maximum temperature (termed upper cutoff) above which development stops. These values can be used in predicting insect activity and appearance of symptoms during the growing season (Wagner *et al*., 1984).

The present work was pointed mainly on the follow aspects:

(1) Relationship between temperature and rate of development, which gives a quantitive expression for this relationship by using thermal accumulation.

(2) Studying certain biological aspects of *A. ipsilon* as a prior to limit its required heat units to be used through forecasting system for establishment IPM program for its control.

(3) The thermal units required to complete the development of different stages to complete one generation, as well as helping in the design of development indexes, used for determining the times required for these stages under fluctuating temperatures in the field. This such points were previously studied by Pedigo, 1991; Younis, 1992; Dahi, 1997; Hashem *et al*., 1997; Dahi, 2003 ; Dahi, 2005 ; Ismail *et al.*, 2005 and Dahi and Abdel-khalek 2006.

MATERIALS AND METHODS

A good number of *A. ipsilon*, larvae were collected from wild host plants at Dakahlya Governorate. The larvae were reared on caster oil leaves under laboratory condition (27 ± 1 °C) for at least four generations before experimentation.

Each of *A. ipsilon* stages was kept under three constant temperatures (20, 25 and 30°C ± 1°C) to determine its rate of development. Eggs were transferred to glass vials (2.0 X 7.5 cm); four replicates of 25 eggs each were used for each of the temperature to be tested.

Observations were made daily to record the time of hatchability. The incubation period and the embryo developmental rates were estimated. Newly hatched larvae were confined in a separate glass tube (7.5 X 2.5 cm) with adequate castor oil leaves (*Ricinus commnuis*) for feeding. Sawdust was placed at the bottom of the tubes and the top was covered with muslin cloth, secured with rubber band and maintained in the incubators running at 20, 25 and 30 °C. The pupae were kept in similar tubes, and under the same conditions, till moth emergence. After being sexed, the newly emerged moths at each temperature were isolated in pairs, each in a separate The pairs of newly emerged of moths were confined in glass oviposition cages, which consisted of a conventional mating glass bells (16 cm. high and 8 cm. diam.)opened at each end. Each cage had suspended piece of cotton wool previously soaked in 10 % sugar solution. This solution was renewed after 48 hours for moths feeding. The cages were provided with strips of muslin, suspended on its wide end as a suitable site for oviposition.

Daily observations for each treatment were made to record the different durations of the embryo, larvae, pupae, pre-oviposition period as well as generation of *A. ipsilon* under experiment conditions.

The rates of development for *A. ipsilon* stages (incubation period, larval duration, pupal duration, pre-oviposition period and generation) were determined by the simple formula (1/t x 100) for three constant temperatures.

Data obtained in the present work were subjected to statistical analysis by regression. The theoretical development thresholds were determined according to the following:

$$Y = a + bx$$

$$t_0 = -a / b \quad \& \quad K = 1 / b$$

Where: (a): Constant term; (b): Regression coefficient; (r): Correlation coefficient; (t_0): lower threshold of development and (K): thermal units (degree-days).

On the other hand, thermal units required for completion of development of each stage were determined according to the equation of thermal summation (Blunk, 1923):

$$K = y\,(T - t_0)$$

Where y = developmental duration of a given stage; T= temperature in degree centigrade; t_0 = lower threshold of development and K = thermal units (degree-days).

RESULTS AND DISCUSSION

Egg stag:

Data in Table (1) show the relationship between *A .ipsilon* incubation period and constant temperatures of 20, 25 and 30°C. This relationship indicated that the required time for completion of egg development decreased as the temperature increased. The means of incubation periods were 6.18, 3.67 and 2.81 days at 20, 25 and 302°C, respectively. Statistically, there are obvious significant differences in *A. ipsilon* incubation period at all the tested constant temperatures**.**

Table (1): Development of *A. ipsilon* eggs under different constant temperatures and its thermal requirements.

Temp. (°C)	**Incubation period (days ± S.E)**	**Expect duration (days)**	**Rate of development %**	**Expect rate of development %**	**t_o (°C)**	**Degree days (dd´s)**
20	6.18 ± 0.04 a	6.02	16.18	16.61		52.6
25	3.67 ± 0.18 b	3.79	27.24	26.37	11.49	49.6
30	2.81 ± 0.02 c	2.77	35.71	36.14		51.8
Average						51.3
L.S.D	0.16					

The threshold of egg development was calculated and illustrated in Fig. (1); it was found to be 11.49°C. The average of thermal units in degree **–** days required for the completion of development of this stage was 51.3 dd's. The three observed values of eggs rate of development at the constant temperature range (20 - 30°C) gave a remarkable good fit to the calculated temperature – velocity line having the formula Y = 1.95 x - 22.4 (Fig. 1).

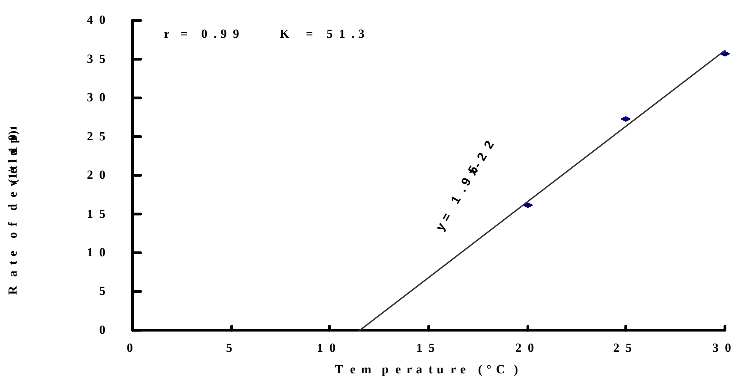

Fig. (1): The regression line of the relation between the rate of development of *A. ipsilon* eggs and different constant temperatures.

Larval stage:

Table (2) indicated that the average larval duration varied from 33.06 days at 20°C to 15.81 days at 30°C. The analysis of variance showed significant differences (P < 0.01) between the means of larval duration at all tested temperatures**.** The lower threshold of development (t_0) for the larval stage was 10.63°C as indicated in Fig. (2).

The same Table showed that the average thermal units required for larval developmental till pupation was 303.5 dd's as determined by the thermal summation equation.

The three observed values for larval rate of development at rang of temperature from 20 to 30°C, gave also a remarkable good fit to the calculated temperature – velocity line having the formula Y =0.33 x -3.51 (Fig.2).

Table (2): Development of *A. ipsilon* larvae under different constant temperatures and its thermal requirements.

Temp. (°C)	**Larvae duration (days ± S.E)**	**Expected duration (days)**	**Rate of development %**	**Expect rate of development %**	**t_o (˚C)**	**Degree days (dd´s)**
20	33.06 ± 0.32 a	32.36	3.02	3.09		309.8
25	20.49 ± 0.33 b	21.14	4.88	4.73	10.63	294.4
30	15.81 ± 0.12 c	15.65	6.32	6.39		306.2
Average						303.5
L.S.D	0.43					

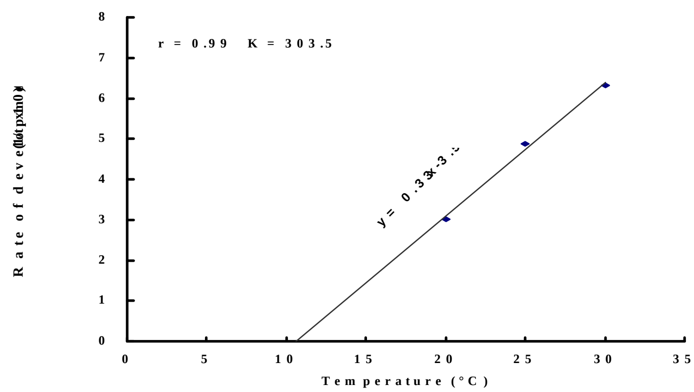

Fig. (2): The regression line of the relation between the rate of development of *A. ipsilon* larvae and different constant temperatures.

Pupal stage

Concerning the effects of the three tested constant temperatures on the pupal duration of *A. ipsilon* (Table 3) it is noticed generally that the pupal period decreased as temperature increased from 20 to 30°C. The average durations were 18.15, 12.00 and 9.12days at 20, 25 and 30 °C, respectively. Statistical analysis referred to significant differences ($P < 0.01$) between the pupal duration and the tested constant temperatures.

Table (3): Development of *A. ipsilon* pupae under different exposure of constant temperatures and its relation with thermal requirements.

Temp. (°C)	**Pupal duration (days ± S.E)**	**Expect duration (days)**	**Rate of developme nt**	**Expect rate of Development %**	**t_o (˚C)**	**Degree Days (DD´s)**
20	18.15 ± 0.15 a	18.05	5.51	5.54		184.6
25	12.00 ± 0.06 b	12.1	8.33	8.26	9.83	182.0
30	9.12 ± 0.09 c	9.09	10.96	10.99		184.0
Average						183.5
L.S.D	0.42					

The developmental zero for this stage was 9.83°C as illustrated graphically by extrapolation in Fig. (3).The average of thermal heat units for *A. ipsilon* pupae was 183.5dd's as estimated by the thermal summation equation.

The three observed values for the pupal rate of development at the temperature range from 20 to 30°C gave a remarkable good fit to the calculated temperature – velocity line having the formula Y = 0.545 x - 5.35 (Fig. 3).

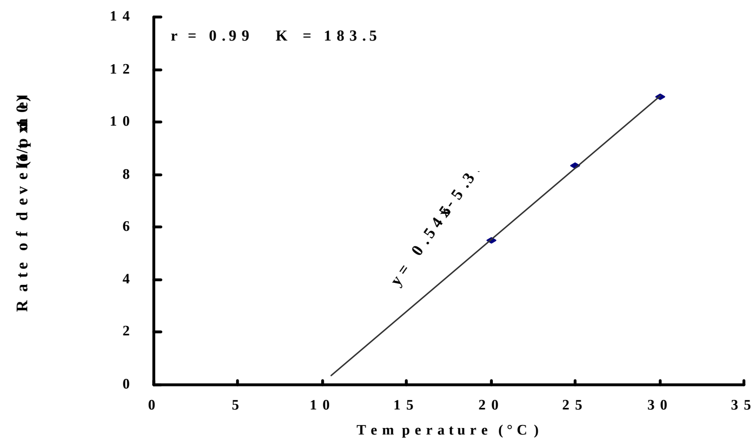

Fig. (3): The regression line of the relation between the rate of development of *A. ipsilon* pupae and different constant temperatures.

Adult stage
1-Pre-Oviposition period

Data in Table (4) show that the mean period required for maturation of the ovaries and starting to egg laying, decreased as the temperature increased (from 4.2 days at 20°C to 2.00 days at 30 °C). The analysis of variance showed significant differences ($P < 0.01$) between the means of the pre-oviposition period at all the tested constant temperatures**.**

Table (4): Duration of *A. ipsilon* pre-Oviposition period under different constant temperatures and its thermal requirements.

Temp. (°C)	**Pre-Oviposition Period (days ± S.E)**	**Expect duration**	**Rate of increase %**	**Expect rate of increase %**	**t_o (˚C)**	**Degree Days (DD´s)**
20	4.2 ± 0.17 a	4.27	23.81	23.41	11.06	37.5
25	2.8 ± 0.33 b	2.73	35.71	36.5		39.0
30	2.00 ± 0.11 c	2.01	50.00	49.6		37.9
Average						38.1
L.S.D	0.37					

The lower threshold of development was 11.06°C. The average of total thermal units was 38.1dd's as calculated by thermal summation equation.

The three observed values for pre-oviposition rate of increase at rang of temperature from 20 to 30°C, gave also a remarkable good fit to the calculated temperature – velocity line having the formula Y = 2.619 x - 28.96 (Fig.4).

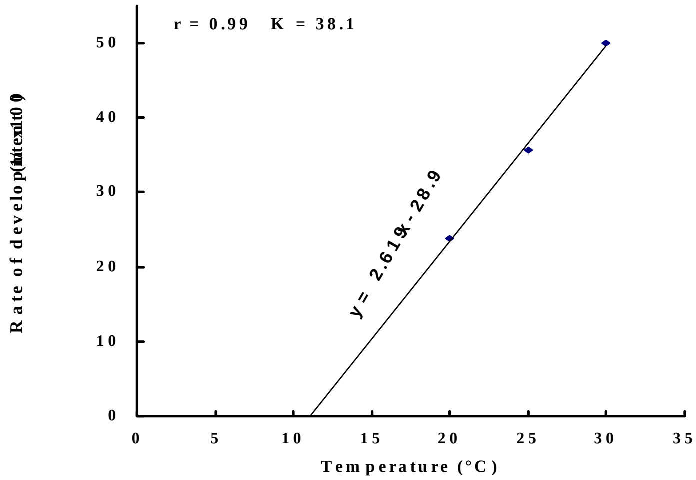

Fig. (4): The regression line of the relation between the rate of development of *A. ipsilon* pre-oviposition period and different constant temperatures.

The generation

The mean duration of generation at different constant temperature regimes could be calculated using the total of mean duration of different developmental stages (i.e. incubation period, larval stage, pupal stage and pre-oviposition period). Theoretically, the results obtained from are method showed an approximate value for mean duration of generation at different constant temperature regimes.

In the present study, the data in Table (5) indicate that the mean duration of generation for *A. ipsilon* was 61.59, 38.96 and 29.73days at 20, 25 and 30 °C, respectively. Data revealed that the increasing of temperature accelerated the developmental rate of *A. ipsilon* where it reached a maximum velocity at 30 °C.

Table (5): Duration of *A. ipsilon* generation under different constant temperatures and its thermal requirements.

Temp. (°C)	**Duration of generation (days ± S.E)**	**Expected duration (days)**	**Rate of increase %**	**Expected rate of increase %**	**t_o (˚C)**	**Degree Days (DD′s)**
20	61.59 ± 1.37 a	60.97	1.62	1.64	10.53	583.3
25	38.96 ± 0.94 b	39.84	2.57	2.51		563.8
30	29.73 ± 0.66 c	29.58	3.36	3.38		578.8
Average						575.3
L.S.D	1.23					

The lower threshold of development (t_0) could be estimated graphically by extrapolation from Fig. (5), it was 10.53°C and the average thermal summation was 575.3 dd's.

These results agreed with the findings obtained by Kajanshikov (1946) who found that the linear relationship between temperature and rate of development can be expressed by the formula K = y (T– t_0). George and phillip (1983) found that the developmental rates increased with increasing of temperature.

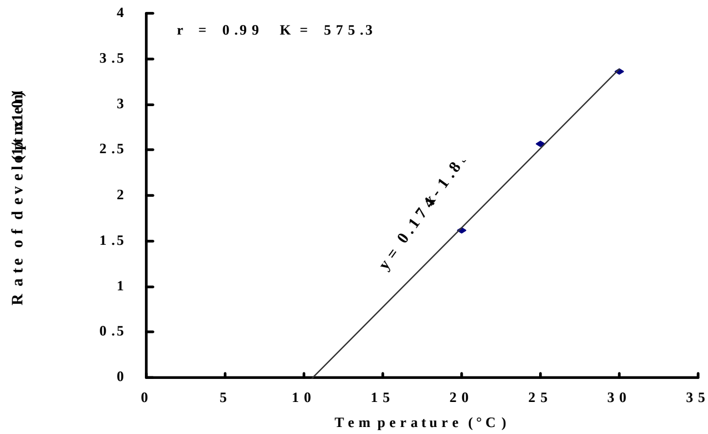

Fig. (5): The regression line of the relation between the rate of development of *A. ipsilon* generation and different constant temperatures.

The results in the present study are in agreement with Gergis *et al.*, (1990); Abdel-Hafez*;* Gergis *et al.,* 1994, Dahi, 1997, Dahi 2005 and Dahi 2006..

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ARABIC SUMMARY

الاحتياجات الحرارية **اللازمة لنمو الدودة القارضة السوداء**

حسن فرج ضاحي – ولاء جميل ابراهيم - **محسن محمد علي**

معهد بحوث وقاية النباتات – **الدقي** – الجيزة.

تهدف الدراسة الحالية الي دراسة تأثير ثلاثة من درجات الحرارة الثابتة (20 ، 25 ،30° م) علي نمو وتطور الاطوار المختلفة للدودة القارضة السوداء اجروتس ابسيلون وذلك لتحديد الثوابت الحرارية للاطوار المختلفة. خلال هذا العمل تم تقدير كل من فترة حضانة البيض ،مدة الطور اليرقي، مدة طور **العذراء، فترة ماقبل** وضع البيض، ومدة الجيل الكامل. **بلغ الحد الحرج للنمو (عتبة النمو الاقتصادي او صفر** النمو البيولوجي) 11.49 °م لطور البيضة، 1063 °م لطور اليرقة، 9.83 °م لطور العذراء ن 11.06 °م لفترة ماقبل وضع البيض 10.53 °م بالنسبة للجيل الكامل (من البيضة الي البيضة).وانتهت الدراسة الي تحديد الاحتياجات الحرارية الازمة لنمو وتطور كل الاطوار وبلغت 51.3 ، 303.5 ، 183.5 ن 38.1 ، 575.3 وحدة حرارية يومية لكل من البيض واليرقات والعذاري وفترة ماقبل وضع البيض والجيل الكامل، **علي التوالي.**