This study was indicated to monitor this cycle and to determine its corresponding temperature requirements.

MATERIALS AND METHODS

To determine the rate of development and the thermal units, laboratory experiment as carried out under controlled conditions of temperature and relative humidity. Susceptible egg-masses strains were obtained from Cotton Leafworm Department, Plant Protection Research Institute. Egg masses were maintained at 27 ±1°C and 70-75 % R.H. The larvae were fed on artificial diet according to Abdel-Hafez *et al.,* (1982). Newly hatched larvae were fed individually in glass vials (2.0 x 7.5 cm) filled to one third with the artificial diet, covered with absorbent cotton and held in the same conditions as mentioned above. The larvae pupate usually on the diet's top or between it parts. At the beginning of pupation, the vials were examined daily for transferring the formed pupae individually to clean vials and to be incubated until moth emergence. Ten pairs of newly emerged moths were confined in glass oviposition that consists of a conventional mating glass bell (16 cm. high and 8 cm. diam) opened at each end. Each mating glass bells was supplied with a small fresh branch of Nerima oleander to serve as an oviposition site and were placed on its wide end on a half petri-dish. Tops of the glass bells were covered with muslin and secured with rubber bands. The glass bells were examined daily to replace *N. oleander* branches with new ones and renew the adult feeding solution (a small piece of absorbent cotton wool previously soaked in 10% sucrose solution). The cages were maintained at the same conditions of temperature and percent R.H. deposited egg masses were kept in petri dishes, and then were available to carry out the proposed work.

Incubators were used to provide constant temperatures of 20, 25, 30, and 35°C ± 1°C. All stages (from egg to adults) were kept under the constant temperatures and % R. H. to determine the developmental rate and all the biological parameters of each stage.

Experimental Design

Eggs were collected from the ovipositional bells and transferred to glass vials (2.0 x 7.5 cm), subsequently the incubation took place under the required combination of temperature and relative humidity. Five replicates of 25 eggs/each were used for each tested degree (i.e. 20, 25, 30 and 35°C). To study the larval development, 125 newly hatched larvae divided in 5 replicate were transferred, each in a separate glass tube (7.5 x 2.5 cm.) as 25 larvae/replicate. The larvae were left in the vials until pupation. Daily observations were made to count the pupated larvae, larval developmental rate and duration was recorded.

Newly formed pupae were collected on the same day of pupation and placed in the glass tube (one pupa for each tube) and covered tightly with a piece of cotton. Five replicates (each of 25 pupae) were placed at each tested temperature and observed daily till adult emergence. Five replicates, each has 2 adults (1 male +1 female), were placed at each tested temperature. Daily observations were made to record the adults survival.

Duration of different stages and other biological aspects were recorded for each temperature degree. Data obtained in the present work were subjected to statistical analysis by regression.

The effects of the above mentioned conditions were tested on the immature and adult stages of CLW the theoretical development thresholds were determined according the following:

$$Y = a + bx$$

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

On the other hand, thermal units required for completion development of each stage was 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 stage

Data in Table (1) shows that the relation between the biological aspects of CLW in different stages and constant temperatures from 20 to 53°C. This relationship indicated that the required time for completion of development decreased as the temperature increased. The means of incubation periods were 7.09, 3.65, 2.98 and 2.29 days at 20, 25, 30 and 35°C, respectively. There were significant differences in the incubation periods at the different temperatures. The same data indicated that the

EGYPTIAN COTTON LEAFWORM *SPODOPTERA LITTORALIS* DEVELOPMENT ON ARTIFICIAL DIET IN RELATION TO HEAT UNITS REQUIREMENTS

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Abstract

The present work was carried out under four constant temperatures (i.e. 20, 25, 30 and 35°C) when the Egyptian cotton leafworm *Spodoptera littoralis* (Boisd.) larvae, where fed on artificial diet. The time required for embryogensis, larval duration, pupal duration and adult longevity decreased as the temperatures increased from 20 to 35°C.The lower thresholds of development (t_0) were 11.86, 7.69, 12.34 and 10.66 °C for egg, larvae, pupae and pre- oviposition periods, respectively. The average of accumulated heat units required for development as 53.2, 314.7, 155.8 and 27.5 degree-days for egg, larvae, pupae and pre-oviposition period, respectively. The lower threshold of development (t_0) for *S. littoralis* when fed on artificial diet to complete the generation was 10.3 °C. The average accumulated heat units required for the generation was 537.2 degree-days .The kind of food had non-significant on heat units requirements.

INTRODUCTION

The Egyptian cotton leafworm (CLW), *Spodoptera littoralis* (Boisd.) has been considered a serious economic pest of cotton and various vegetable and field crops allover the year in Egypt.

Previous studies of CLW developmental times have been reported by Nasr, 1962. The influence of temperature in determining the development time of insect population is well established (Ives, 1973).

On the other hand, Wagner *et al.*, (1984) described the developmental rates as a function of temperature. However, little attempts have been made on the use of temperature accumulation as an aid in forecasting the various stages of this pest (El-Shafei *et al.*, 1981, Younis, 1992, Dahi, 1997, Hashem, 1997 and Dahi, 2003).

To obtain information on the temperature threshold and temperature accumulation for *S. littoralis* studies were conducted on four constant temperatures. Degree-days represent the accumulation of heat units over a minimum temperature for a 24-hour period. Below this minimum temperature, no development takes place, but above it, heat units are accumulated towards development (Pedigo, 1991).

The data revealed that the tested constant temperatures demonstrate variable effects on the weight of the two sexes of pupae of CLW. The average of the weight of male and female pupae decreased with the increasing of temperature from 20 to 35°C. The heaviest weights were 33.4 mg for male and 35.4 mg for female at 20°C, while the lightest was 16.3 mg for male and 24.4 mg for female at 35°C.

The developmental zero for this stage was 12.34°C as illustrated graphically by extrapolation in Fig. (3). Data in the same Figure refer that the average of thermal heat units for CLW pupae was 155.8 DD's as estimated by the thermal summation equation K = y (T – 12.34). On the other hand, when the larval stage feed on caster oil leaves according Dahi, 1997, the pupal lower threshold of development was 12.32 °C and the average of total thermal units was 148.81 DD's.

The four observed values for the pupal rate of developmental at the temperature range from 20 to 35°C, gave a remarkable good fit to the calculated temperature – velocity line having the formula Y = 0.64 x – 7.94.

Adult stage

1- Pre-oviposition period

Data in Table (1) show that the mean time required for maturation of the ovaries and starting to egg laying, decreased as the temperature increase from 2.75 days at 20°C to 1.11 days at 35 °C. The lower threshold of development was 10.66°C. The average of total thermal units was 27.5 DD's as calculated by thermal summation equation K = y (T – 10.66). When CLW fed on caster oil leaves the lower threshold of development for this period was 10.16°C, while the average thermal units was 24.68 DD's (Dahi 1997) .

2-Fecundity

Data in Table (1) show that the adult female deposited eggs under all tested temperature degrees. The average total number of egg laid by female throughout their life span as 397, 1210, 809 and 45 eggs at 20, 25, 30 and 35°C, respectively.

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 these method shows an approximate value for mean duration of generation at different constant temperature regimes.

newly hatched larvae divided in 5 replicate were transferred, each in a separate glass tube (7.5 x 2.5 cm.) as 25 larvae/replicate. The larvae were left in the vials until pupation. Daily observations were made to count the pupated larvae, larval developmental rate and duration was recorded.

Newly formed pupae were collected on the same day of pupation and placed in the glass tube (one pupa for each tube) and covered tightly with a piece of cotton. Five replicates (each of 25 pupae) were placed at each tested temperature and observed daily till adult emergence. Five replicates, each has 2 adults (1 male +1 female), were placed at each tested temperature. Daily observations were made to record the adults survival.

Duration of different stages and other biological aspects were recorded for each temperature degree. Data obtained in the present work were subjected to statistical analysis by regression.

The effects of the above mentioned conditions were tested on the immature and adult stages of CLW the theoretical development thresholds were determined according the following:

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RESULTS AND DISCUSSION

Egg stage

Data in Table (1) shows that the relation between the biological aspects of CLW in different stages and constant temperatures from 20 to 53°C. This relationship indicated that the required time for completion of development decreased as the temperature increased. The means of incubation periods were 7.09, 3.65, 2.98 and 2.29 days at 20, 25, 30 and 35°C, respectively. There were significant differences in the incubation periods at the different temperatures. The same data indicated that the highest percentage of hatchability was 98.4 % at both of 25 and 30°C, whereas the lowest ones was 23.2 % occurred at 35°C.

The threshold of egg development was calculated and illustrated in Fig. (1), it was found to be 11.86°C. The average of thermal units in degree – days required for the completion of development of this stage was 53.2 DD's, Dahi (1997) estimated the zero of development of CLW fed on natural food (caster oil leaves). He found that the egg lower threshold of development was 11.85 °C and the average of thermal heat units required for the egg development was 52.15 DD's.

The four observed values of egg's rate of development at the constant temperature range (20 - 35°C), gave a remarkable good fit to the calculated temperature – velocity line having the formula Y = 1.89 x – 22.5 (Fig. 1).

Larval stage

Table (1) indicated that the average larval duration varied from 25.5 days at 20°C to 11.4 days at 35°C. The lower threshold of development (t_0) for the larval stage was 7.69°C as indicated in Fig. (2).

The pupation percent were 56.8, 88.8, 50.4 and 17.0 % at 20, 25, 30 and 35°C, respectively. Generally, the developmental rates of the CLW increased with the increasing of temperatures from 20 to 35°C. The same Figure showed that the average thermal units required for larval developmental till pupation was 317.7 DD's as determined by the thermal summation equation K= y (T-7.69). This results when the insect was feed on artificial diet, but when feed on caster oil leaves the lower threshold of development and the average thermal units for this stage were 7.57°C and 306.38 DD's, respectively, according Dahi (1997).

The four observed values for larval rate of development at rang of temperature from 20 to 35°C, gave also a remarkable good fit to the calculated temperature – velocity line having the formula Y = 0.3 x -2.44 (Fig. 2).

Pupal stage

Concerning the effects of the four tested constant temperatures on the pupal duration of CLW (Table 1) it is noticed generally that the pupal period decreased as temperature increased from 20 to 35°C. The average durations were 20.5, 12.5, 8.4 and 7.0 days at 20, 25, 30 and 35°C, respectively. The same Table indicated that the highest percentage of adult emergence was 82% occurred at 25°C, while the lowest percentage was 36% at 35°C.

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In the present study, the data in Table (1) indicates that the mean duration of generation for cotton leafworm were 55.9, 36.2, 27.2 and 21.8 days at 20, 25, 30 and 35°C, respectively. Data reveled that the increasing of temperature accelerated the developmental rate of CLW where it reached the maximum velocity at 35°C.

Thermal summation method, represents the hyperbolic relationship between temperature and developmental times given by equation: $Y (T - 10.3) = 537.2$ DD's, that drive from the linear regression equation: $Y = 0.19 x - 1.92$ ($r = 0.99$). The lower threshold of development (t_0) could be estimated graphically by extrapolation from the Fig. (5), it was 10.3°C. The complete development of the generation required 542.2, 532.1, 535.8 and 538.5 DD's with an average 537.2 DD's as shown in Fig. (2). Dahi, 1997 reported that the *S. littoralis* lower threshold of development and the average thermal units were 10.14 °C and 523.27 DD's, respectively to complete the whole generation on natural food (caster oil leaves).

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 $K = y (T - t_0)$. Gergis *et al.,* (1994) investigated the relationship between temperature and developmental rates for the cotton leafworm under field and laboratory conditions. They reported that the different stages of *S. littoralis* completed their development at the range of temperatures from 15 - 32.5 °C, under this conditions the threshold of development and thermal units were also estimated.

On the other hand, Nasr *et al.,* 1973 stated that there was a tendency for adult life span of CLW to be reduced with high temperature and the female fecundity was adversely affected by high temperature, where the highest mean number of eggs/female was 966 at 30°C, while the lowest number was 145 eggs/ female. George and phillip (1983) found that the developmental rates of codling moth, *C. pomenella* increased with increasing of temperature.

The results in the present study concerning adult stage aspects are in agreement with Gergis *et al.,* (1990) on *Earias insulana,* Abdel-Hafez 1993 on *Pectinophora gossypiella,* Gergis *et al.,* 1994 and Dahi, 1997 on *S. littoralis.*

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Table 1. The biological aspects for *Spodoptera littoralis* stages fed on artificial diet at constant temperatures.

Stages	Temperatures (°C)			
	20	25	30	35
Incubation period	7.09 ± 0.03	3.65 ± 0.01	2.98 ± 0.03	2.29 ± 0.2
1st instar larvae	3.10 ± 0.19	2.26 ± 0.08	1.81 ± 0.09	1.84 ± 0.18
2nd instar larvae	2.45 ± 0.19	2.35 ± 0.10	1.50 ± 0.08	1.47 ± 0.22
3rd instar larvae	2.86 ± 0.28	1.9 ± 0.15	1.37 ± 0.09	1.37 ± 0.26
4th instar larvae	3.27 ± 0.25	2.17 ± 0.23	1.83 ± 0.09	1.04 ± 0.17
5th instar larvae	4.40 ± 0.25	2.52 ± 0.10	2.29 ± 0.08	1.47 ± 0.25
6th instar larvae	9.42 ± 0.25	6.8 ± 0.14	5.6 ± 0.19	4.23 ± 0.27
Larval duration	25.5 ± 0.32	18.0 ± 0.13	14.4 ± 0.12	11.4 ± 0.16
Pupal duration	20.5 ± 0.4	12.5 ± 0.11	8.4 ± 0.14	7.0 ± 0.5
Pre-oviposition Period	2.75 ± 0.12	2.05 ± 0.08	1.44 ± 0.06	1.11 ± 0.06
Total generation	55.9 ± 1.53	36.2 ± 0.7	27.2 ± 0.93	21.8 ± 0.77
Hatchability %	88.0	98.4	98.4	23.2
Pupation %	56.8	88.8	50.4	17.0
Male pupal weight	0.334 ± 0.014	0.314 ±0.007	0.276 ± 0.009	0.163 ± 0.008
Female pupal weight	0.354 ± 0.008	0.341 ±0.007	0.288 ± 0.007	0.244 ± 0.006
Emergence %	53.5	82	50	36
Fecundity	397	1210	809	45
Normal pupae %	100	95.5	100	100
Normal moths %	58	84.6	67.7	0
Sex ratio % (M : F)	11: 89	51 : 49	48 : 52	67 : 33

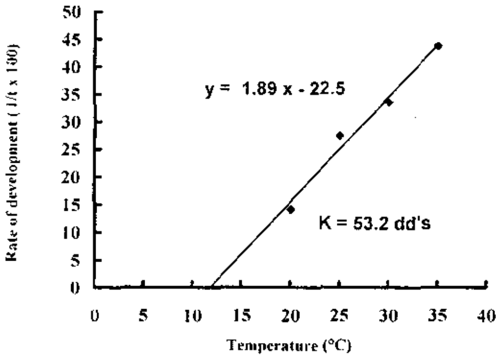

Fig. (1): The regression line of the egg stage of *S. littoralis* at different constant temperatures.

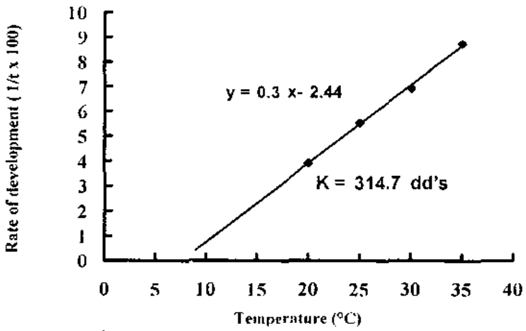

Fig. (2): The regression line of the larval stage of *S. littoralis* at different constant temperatures.

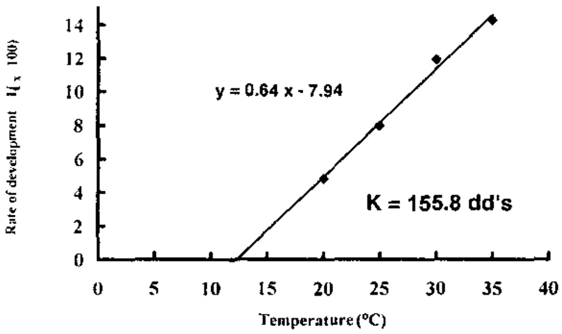

Fig. (3): The regression line of the pupal stage of *S. littoralis* at different constant temperatures

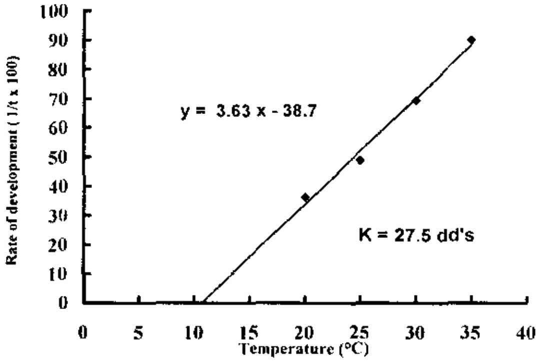

Fig. (4): The regression line of the pre- oviposition pereiod of *S. littoralis* at different constant temperatures.

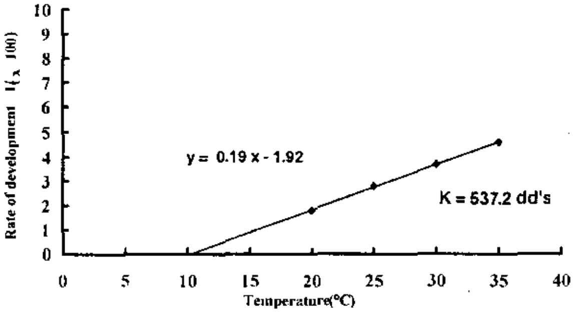

Fig. (5): The regression line of the complet generation *S. littoralis* at different constant temperatures

تطـــــــــور دودة ورق القطن المصرية علي البيئة الصناعية وعلاقتها بالوحدات الحرارية المتراكمـــــــة

حسن فرج ضاحي

معهد بحوث وقاية النباتات – مركز البحوث الزراعية

أجري هذا العمل تحت تأثير درجات الحرارة الثابتة في المدى من ٢٠ الـــي ٣٥ ٥م عنـــدما كانت دودة ورق القطن المصرية متغذية علي البيئة الصناعية، حيث اوضحت النتائج ان الوقت الازم لاتمام نمو وتطور الاطوار المختلفة يتناسب عكسيا مع درجة الحرارة في المدى من ٢٠ – ٣٥ ٥م . بلغ صفر النمو البيولوجي ١١,٨٦ ، ٧,٦٩ ، ١٢,٣٤ ، ١٠,٦٦ ٥م لكل من البـــيض ، اليرقـــات ، العذارى ، وفترة ما قبل وضع البيض ، علي التوالي. بلغ متوسط الوحدات الحرارية الازمـــة لنمـــو وتطور كل من الاطوار السابقة ٥٣,٢ ، ٣١,٧ ، ١٥٥,٧ ، ٢٧,٥ وحدة – يـــوم علـــي التـــوالي . وانتهت الدراسة الي ان صفر النمو البيولوجي وعدد الوحدات الحرارية للجيـــل الكامـــل ١٠,٣ ٥م ، ٥٣٧,٢ وحدة حرارية يومية وذلك عند تغذية الطور اليرقي علي البيئة الصناعية والتـــي لاتختلـــف معنويا مع مثيلاتها عند تغذية الطور اليرقي لنفس الآفة علي الغذاء الطبيعي (ورق الخروع) ، أي ان نوع الغذاء ليس له دور في العدد التراكمي للوحدات الحرارية الازمة لنمو وتطور دودة ورق القطن المصرية.وهذه التقنية/متر تكون مفيدة للغاية عند تطبيق برامج الادارة المتكاملة لمكافحة الآفات.