THRESHOLD TEMPERATURES AND THERMAL REQUIREMENTS OF THE LESSER COTTON LEAFWORM *SPODOPTERA EXIGUA* HB.

HASSAN F. DAHI AND SAMAH. M. ABDEL-KHALEK
Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt.

(Received 30-10-2006)

INTRODUCTION

In Egypt, the lesser cotton leafworm *Spodoptera exigua* attacks a wide variety of hosts, the most important of which are cotton and maize (Mourad, 1977). This pest caused considerable damage to young cotton plants (Willcocks and Bahgat 1937). The egg masses of *S. exigua* on cotton are hand picked along with those of *S. littoralis*, and chemicals used to control the later pest are, as a rule more effective against *S. exigua*.

The influence of temperature in determining the emergence development of insect population is well established (Davidson, 1944 and Ives, 1973). Since the temperature is considered as an important environmental factor that affects the rate of development of the insects, and controlled the success of the insect to live in a given temperature, it was particularly interesting as practical point of view for economic insects to obtain a useful and good forecast and prediction system of insect population Wagner *et al.*, (1984).This work was pointed mainly on the following aspects: (1) Relationship between temperature and rate of development, which give a quantitive expression for this relationship, using thermal accumulation. (2) Studying the biological aspects of *S .exigua* as a perior to limit its required heat units to be used through forecasting system for establishment of an IPM program for *S .exigua*. (3) The thermal units required to complete the development of different stages to a complete one generation, as well as helping in the design of development indices, used for determining the times required for these stages under fluctuating temperatures in the field. Such points were previously studied by (El-Shafei *et al.*, 1981; Younis, 1992; Dahi, 1997; Hashem, 1997, Dahi, 2003 , Dahi, 2005 and Ismail *et al.*, 2005).

To obtain information on the temperature threshold and temperature accumulation for *S .exigua,* studies were conducted on three 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 took place, but above it, heat units are accumulated towards development (Pedigo, 1991).

MATERIAL AND METHODS

A good number of *S. exigua* egg masses were collected from wild host plants at Assuit Governorate, Diroutt District. The larvae were reared on caster oil leaves *Ricinus commnuis* which seems to be the most nutritive plant leaves for the larvae of *S. exigua,* (Mourad, 1977) under laboratory condition (27 ± 1 °C) for four generation at least to become susceptible strain.

The *S. exigua* stages were kept under three constant temperatures (20, 25 and 30 °C) to determine the 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 situations to be tested.

Observations were made daily to record the time of hatchability. The incubation period and the embryo development rates were estimated during this experiment. Newly hatched larvae were confined in a test tube (7.5 X 2.5 cm) with adequate castor oil leaves for feeding. Sawdust was placed at the bottom of the tubes and the top was covered with muslin cloths, secured with rubber band and maintained in the incubators running at 20, 25 and 30 °C. The pupae were kept in similar tubes, under the same conditions, till moth emergence. After being sexed, the newly emerged moths of each group resulted from the same temperature were isolated in pairs, one pair for each kept in a separate tube (15 cm long 5 cm diam.) opened at each ends, contains a small piece of absorbent cotton wool previously soaked in 10% sucrose solution as adult feeding solution . The two ends of each tube were covered with muslin cloths, secured with rubber band, and a small branch of *Nerium oleander* served as 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 S. *exigua* under the experimental conditions.

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

Duration of different stages was 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 *S. exigua,* the theoretical development thresholds were determined according the following formula:

$$Y = a + bx$$

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

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).

RESULT AND DISCUSSIONS

Egg stag:

Data in Table (1) and Fig. (1) show the relation between the *S. exigua* incubation period and constant temperatures from 20 to 30°C, and indicated that the required time for completion of egg development decreased as the temperature increased. The means of incubation periods were 5.35, 2.97 and 2.15 days at 20, 25 and 30°C, respectively.

The threshold of egg development was calculated and illustrated in Fig. (1), it was found to be 13.15 °C. The average of thermal units in degree – days required for the completion of development of this stage was 36.0 DD's. The three observed values of egg's rate of development at the constant temperatures, 20, 25 & 30°C, gave a remarkable good fit to the calculated temperature – velocity line having the formula Y = 2.78 x – 36.59 (Fig. 1).

Larval stage:

Table (2) indicated that the average larval duration varied from 19.4 days at 20°C to 9.74 days at 30°C. The lower threshold of development (t_0) for the larval stage was 9.64°C as indicated in Fig. (2).

The same Table showed that the average thermal units required for larval development till pupation was 196.1. DD's as determined by the thermal summation equation K= y (T-9.64).

The three observed values for larval rate of development at the three tested temperature degrees, gave also a remarkable good fit to the calculated temperature – velocity line having the formula Y = 0.511 X -4.92 (Fig.2).

TABLE (I)

Development of *S. exigua* eggs under different exposure of constant temperatures and its relation with thermal requirements.

Temp. (°C)	Incubation period	Rate of development	t_0 (°C)	Expected		Degree days
				Duration	Rate of development	
20	5.35 ± 0.24	18.69	**13.15**	5.25	19.04	36.64
25	2.97 ± 0.12	33.67		3.03	32.95	35.19
30	2.15 ± 0.09	46.51		2.13	46.86	36.22
Average						**36.0**

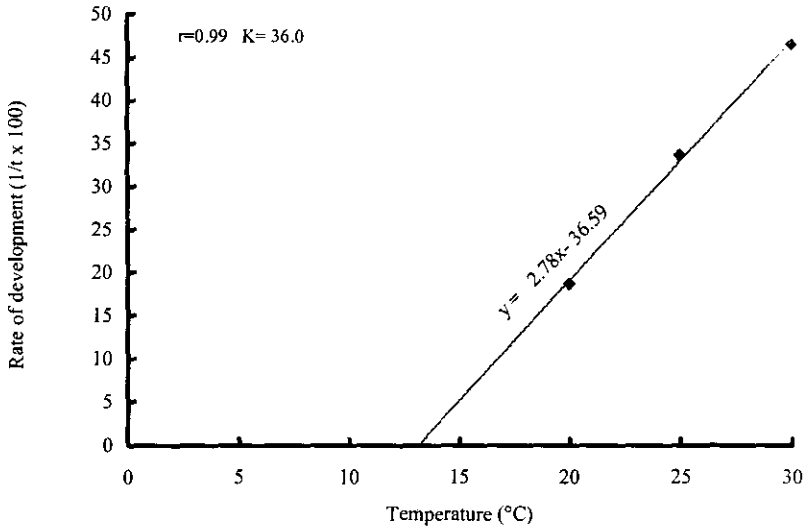

Fig. (1): The regression line of the relation between the rate of development of S.exigua eggs and different constant temperatures.

Concerning effects of the three tested constant temperatures on the pupal duration of *S. exigua,* it was noticed generally that the pupal period decreased as temperature increased where the average durations were 13.11, 7.41 and 6.0 days at 20, 25 and 30 °C, respectively (Table 3).

The developmental zero for this stage was 11.07°C as illustrated graphically by extrapolation in Fig. (3). Data in the same table refers that the average of thermal heat units for *S. exigua* pupae was 111.29 DD's as estimated by the thermal summation equation K = y (T – 11.07).

The three observed values for the pupal rate of development gave a remarkable good fit to the calculated temperature – velocity line having the formula Y = 0.90 X– 10.01 Fig. (3).

TABLE (II)

Development of *S. exigua* larvae under different exposure of constant temperatures and its relation with thermal requirements.

Temp. (°C)	Larval duration	Rate of development	t_0 (°C)	Expected		Degree days
				Duration	Rate of development	
20	19.4 ± 0.22	5.15	**9.64**	18.9	5.29	201.0
25	12.30 ± 0.09	8.13		12.75	7.84	189.0
30	9.74 ± 0.49	10.26		9.61	10.4	198.3
Average						**196.1**

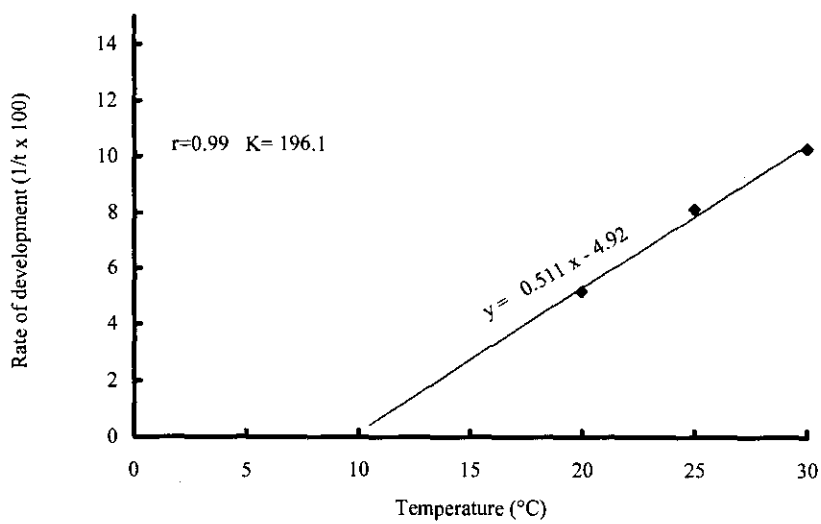

Fig. (2): The regression line of the relation between the rate of development of S.exigua larvae and different constant temperatures.

Adult stage

Pre-oviposition period

Data in Table (4) show that the mean time required for maturation of the ovaries and starting to egg laying decreased as the temperature increased from 2.7 days at 20°C to 1.4 days at 30 °C. The lower threshold of development was 9.64°C. The average of total thermal units was 29.06 DD's as calculated by thermal summation equation K = y (T – 9.64). The three observed values for this period 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 = 3.44 X - 33.15 (Fig.2).

The generation

Theoretically the mean duration of total period 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).

In the present study, the data in Table (1) indicates that the mean durations of generation for cotton leafworm were 40.57, 24.68 and 19.29 days at 20, 25 and 30°C, respectively. Data reveled that increasing of temperature accelerated the developmental rate of *S. exigua* where it reached the maximum velocity at 30 °C.

Thermal summation method, represents the hyperbolic relationship between temperature and developmental times given by equation: Y (T – 10.67) = 368.3 DD's, that was drived from the linear regression equation: Y = 0.272 X – 2.9 (r = 0.99). The lower threshold of development (t_0) that could be estimated graphically by extrapolation from the Fig. (5), was 10.67°C.

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 these 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 *S. littoralis* to be reduced with high temperature. George and

phillip (1983) found that the developmental rates of codling moth, *Carpocapsa. 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, Dahi, 1997 and Dahi 2005 on *S. littoralis.*

TABLE (III)

Development of *S. exigua* Pupae under different exposure of constant temperatures and its relation with thermal requirements.

Temp. (°C)	Pupal duration	Rate of development	t_0	Expected		Degree days
				Duration	Rate of development	
20	13.11 ± 0.11	7.62	**11.07**	12.39	8.07	117.07
25	7.41 ± 0.11	13.49		7.94	12.59	103.22
30	6.0 ± 021	16.66		5.84	17.11	113.58
Average						**111.29**

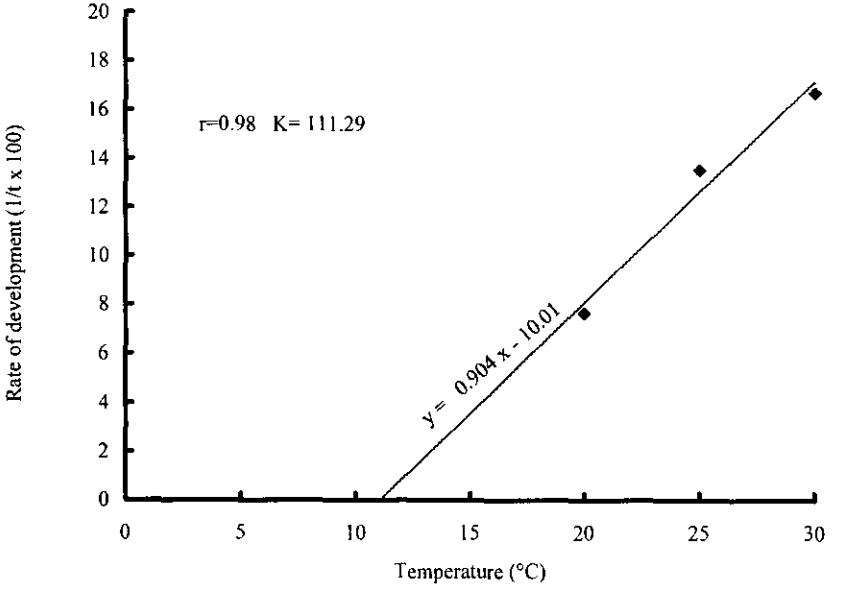

Fig. (3): The regression line of the relation between the rate of development of S.exigua pupae and different constant temperatures.

TABLE (IV)

Development of *S. exigua* Pre –oviposition period under different exposure of constant temperatures and its relation with thermal requirements.

Temp. (°C)	Pre- oviposition period	Rate of development	t_0	Expected		Degree days
				Duration	Rate of development	
20	2.7 ± 0.11	37.03	**9.64**	2.8	35.62	27.97
25	2.00 ± 0.35	50.0		1.89	52.81	30.72
30	1.4 ± 0.21	71.42		1.42	70.01	28.5
Average						**29.06**

TABLE (V)

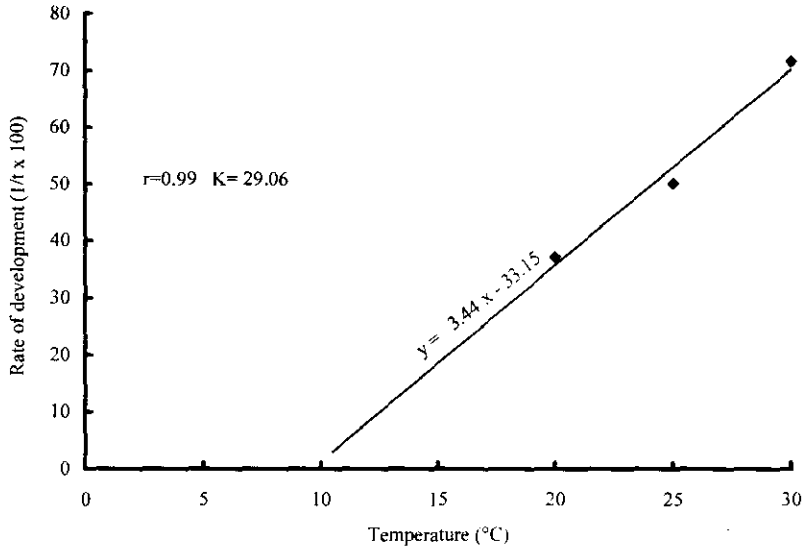

Fig. (4): The regression line of the relation between the rate of development of S.exigua pre-oviposition period and different constant

Development of *S. exigua* Generation under different exposure of constant temperatures and its relation with thermal

Temp. (°C)	Duration of generation	Rate of development	t_0	Expected		Degree days
				Duration	Rate of development	
20	40.57 ± 0.68	2.46	**10.67**	39.52	2.53	378.51
25	24.68 ± 0.67	4.05		25.7	3.89	353.66
30	19.29 ± 1.0	5.18		19.04	5.25	372.87
Average						**368.3**

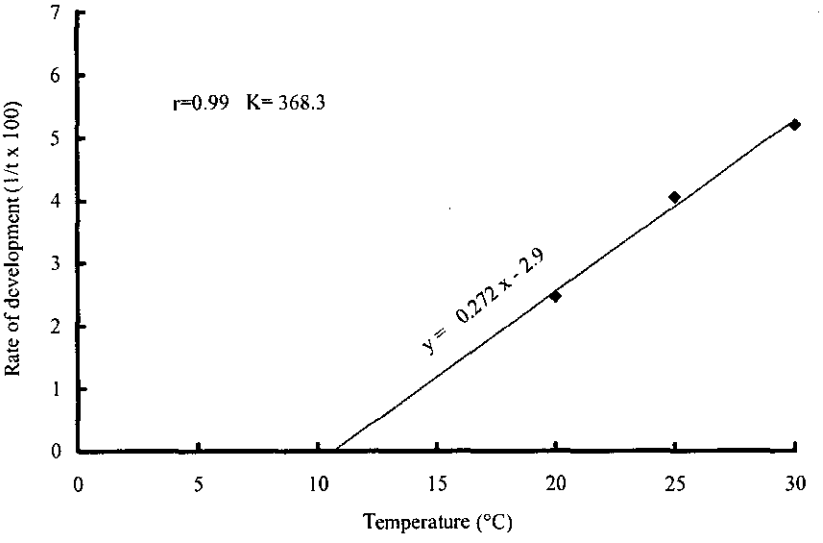

Fig. (5): The regression line of the relation between the rate of development of S.exigua generation and different constant temperatures.

SUMMARY

The present investigation aimed to study the effect of three constant temperatures (20, 25, and 30°C) on the developmental rates of different stages of the lesser cotton leafworm *Spodoptera exigua*. 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. The threshold temperatures were 13.15°C for egg, 9.64 °C for larvae, 11.07 °C for pupae 9.64°C for pre-oviposition period and 10.67 °C for generation. The average thermal requirements needed for completing the development were 36.0, 196.1, 111.29; 29.06 and 368.3 degree-days for egg, larvae, pupae, pre-oviposition period and generation, respectively.

REFERENCES

ABDEL-HAFEZ, A.; S. H. TAHER; G. M. MOAWAD and KH. GH. EL-MALKI (1993): The combined effect of high temperature and exposure period regimes on some biological aspects of pink bollworm *Pectinophora gossypiella* (Saund.). *(Egypt. J. Appl. Sci., 8 (7): 485-493).*

BLUNK, M. (1923): Die Entwicklung von *Dytiscus marginalis* L.vom Ei bis zur Imago, *(Teil. 2, Die Metamorphase Zracht-Wiss. Sool, 121-171).*

DAHI, H. F. (1997): New approach for management the population of cotton leafworm *Spodoptera littoralis* (Boisd.) and pink bollworm *Pectinophora gossypiella* (Saund.) in Egypt. *(Unpublished M. Sc. Thesis, Fac. Agric., Cairo University, 149 pp).*

DAHI, H. F. (2003): Predicting the annual generations of the spiny bollworm *Earias insulana* (Boisd.) (Lepidoptera: Archtidae). *(Unpublished Ph. D. Thesis, Fac. Agric., Cairo Univ., 182 pp).*

DAHI, H. F. (2005): Egyptian cotton leafworm *Spodoptera littoralis* development on artificial diet in relation to heat unit requirements. *(Egypt. J. Agric. Res., 83 (1), 199-209).*

DAVIDSON, J. (1944): On the relation between temperature and rate of development of insects at constant temperatures. *(J. Anim. Ecol., 13: 26-38).*

EL-SHAFEI, S. A.; R. R. ISSHAK and E. A. NASR (1981): Seasonal abundance of the cotton leafworm moths, *Spodoptera littoralis* (Boisd.) in relation to the accumulated heat. *(Res. Bull., Fac. Agric., Ain Shams Univ., 1-5).*

GEORGE, C. R. and S. L. PHILLIP (1983): Developmental rates of codling moth (Lepidoptera: Olethreutidae) reared on apple at four constant temperatures. *(Environ. Entomol., 12 (3) : 831-834).*

GERGIS, M. F.; M. A. SOLIMAN; E . A. MOFTAH and A. A. ABDEL-NABY (1990): Temperature-Development relationship of spiny bollworm *Earias insulana* (Boisd.). *(Assiut J. Agric. Sci., 21 (3): 129-139).*

GERGIS, M. F.; M. A. RIZK; M. A. MAKADEY and A. HUSSEIN (1994): Relationship between temperature and rate of development of cotton leafworm *Spodoptera littoralis* (Boisd.). *(Minia J. Agric. Res. & Dev., 14).*

HASHEM, M. Y.; I. I. ISMAIL; S. A. EMARA and H. F. DAHI (1997): Seasonal fluctuations of the pink bollworm, *Pectinophora gossypiella* (Saund.) and prediction of generations in relation to heat units accumulation. *(Bull. Entomol. Soc. Egypt, 75: 140-151).*

ISMAIL, I.I.; M. Y. HASHEM; S. A. EMARA and H.F. DAHI (2005): Heat requirements for spiny bollworm, *Earias insulana* (Boisduval) (Lepidoptera: Arctiidae). *(Bull. Entomol. Soc. Egypt, 82: 255- 265).*

IVES, W. G. H. (1973): Heat units and outbreaks of *Malacosoma disstria. (Can. Entomol. 105, 529,543).*

KAJANSHIKOV, N.B. (1946): Kbonpocy oxnbhehhom tempnueckom ontnmyme 8-olabnlbhoctn npuoueccob pazbntna hacekomblx bothowehnn tempnuecknx *(bilnahnn-300-Lx4 Prl. 25, C. 27-35).*

MOURAD S. A. (1977): Studies on *Spodoptera exigua* Hb. on corn in A.R.E. *(Unpublished M. Sc. Thesis, Fac. Agric., Ain Shams University, 80 pp).*

NASR, E.A.; K. EL-RAFIE; M.M. HOSNY and A. BADAWI (1973): Effect of temperature and relative humidity on the life cycle of the cotton leafworm, *S. littoralis. (Bull. Soc. Entomol., Egypt, 27: 139-144).*

PEDIGO, L. P. (1991): Entomology and pest management text book. *(Macmillan Publishing Company, New York, pp.197-198).*

WAGNER, T. L.; H. I. WU; P. J. H. SHARPE; R. M. SCHOOLFIELD and R. N. COULSON (1984): Modeling insect development rates: A literature review and application of a biophysical model. *(Ann .Entomol. Soc. Amer., 77: 208-225).*

WILLCOCKS, F.C. and BAHGAT, L. (1937): The insects and related pests in Egypt. *(Vol. I., Royal Agri. Soci. Ent. Cairo).*

YOUNIS, A. M. (1992): Some biological aspects of cotton leafworm, *Spodoptera littoralis* (Boisd.) under different temperature regimes. *(Bull. Entomol., Soc., Egypt, Vol. 70: 171-184).*