USING THE HEAT REQUIREMENTS FOR PREDICTING THE ANNUAL GENERATIONS OF THE SPINY BOLLWORM *EARIAS INSULANA* (BOISD.) ON COTTON PLANTS AT UPPER EGYPT

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INTRODUCTION

The spiny bollworm *Earias insulana* (Boisd.) is a polyphagous pest causing damage to cotton, maize and vegetables. Since it largely feeds on the reproductive parts of plants, controlling it with chemical insecticides is often difficult. In order to develop nonchemical method for its management Valand and Patel 1993).

Although the use of insecticides is still the most effective method to control pests, it is becoming increasingly important to design and develop an alternative program safe to man and/ or environment. Integrated pest management program involves a total system for suppression of pest population, depending on predicting the seasonal population cycles of insects, leding to the formulation of many mathematical methods (Clement *et al.*, 1979; Richmond *et al.* 1983), which described the developmental rates as a function of temperature (Wagner *et al.*, 1984). Also, Taman (1990) stated that pheromone traps provided a useful ecological tool for monitoring cotton insect pests and early prediction of their successive generations.

In present ecological studies were carried out for forecasting and monitoring population systems on the basis of the seasonal fluctuations and annual generations of the spiny bollworm according to the number of males attracted and captured by the pheromone baited traps and the heat units required for completing each generation. Several authors studied the role of environmental factors and the thermal units accumulations (dd's) as a mean for forecasting moth population peaks (Chu and Hennebrry (1992), Metwally *et al.*, (1993), Abdel-Maguid and Amin (1994) on *Pectinophora gossypiella*, Korat and Lingappa (1995) on some bollworm moths (*P. gossypiella, Earias insulana and Helothis armigera*); Emara *et al.*, (1999) on *Spodoptera littoralis* and Al Beltagy (1999) on *E. insulana*.

A number of workers have reported about sex pheromone traps and heat requirements for lepidopterous insect pests (Davidson 1944; Sevacherian *et al.*, 1977; Potter *et al.*, 1981; Moftah *et al.*, 1988; Abdel - Meguid and Amin 1994; Khidr *et al.*, 1995; Dahi 1997; Sing *et al.*, 2004 and Ismail *et al.*, 2005).

The goal of this work is to clarify the relationship between temperature and number of male moths captured by pheromone traps in determining the emergence and development of *E. insulana* population and using the heat unit summation method to expect their population peaks to help for timing control measures in cotton field.

MATERIAL AND METHODS

This work was conducted at Sanores and Malawi districts at Fayoum and Minia Governorates, respectively, for three successive cotton seasons (1998, 1999 and 2000) using the sex pheromone traps (funnel trap) described by Rashad (1981). Each season extended from the 1^{st} of May to the $21^{st}$of September. The traps were baited with the synthetic pheromone formulation in polyethylene vials. Every vial contained one mg. of the active ingredient of the specific pheromone for *E. insulana* (Hummel *et al.*, 1973 and Hall *et al.*, 1980).

The traps were fixed in the cotton fields on steel stands and placed above the cotton canopy with a distance of about 20 cm high and were kept in the same level till the end of the season, (Dhawan and Sidhu, 1988).

Five traps were hung and distributed randomly in cotton fields by the rate of one trap /10 Feddans. The cotton area in both Governorates was cultivated with cotton variety Giza 83. The whole cotton plants in the two Governorates were subjected to normal agricultural processes.

As a frequent routine, the backing of the funnel traps was changed monthly and replaced by new ones. The pheromone vials were replaced every two weeks. The catch of *E. insulana* males were collected, counted and recorded every 3 days.

Daily maximum and minimum temperatures were records from the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Dokki, Giza, and Degree-days (DD) were calculated from the daily maximum and minimum temperatures (°C) with developmental threshold (t_0) 9.9°C as previously estimated by Ismail *et al.*, (2005) for the spiny bollworm, *Earias insulana*. Hereinafter, the following formula was used for computing the heat units (DD) according to Richmond *et al.*, (1983):

$$H = \sum HJ$$

Where: H = number of heat units to emergence;

HJ = (max. + min./2-C,	if max.>C & min.>C.
= (max. - C)2/(max. - min.),	if max.>C & min<C.
= 0	if max. <C & min.<C.

C = threshold temperature.

RESULTS AND DISCUSSION

The average of thermal units (degree-days) required for one generation of spiny bollworm which has been estimated during the same study (Ismail *et al.*, 2005) was 499.57 dd's.

Number of generations for every cotton season was determined by the computed averages of accumulated temperatures between the real peaks of adult emergence *i.e.*, observed peaks (according to the number of captured male moths by pheromone traps) taking into consideration the average of generation from oviposition to adult emergence (499.57 dd's) that has been obtained as mentioned before. As a result, prediction of the subsequent generation could be described.

Three main generations were observed in cotton field in addition to the winter one which started by the 1st of January on different prevailing host plants and extended to the cotton season where its male moths reached their peak on cotton plants.

The calculated requirement of thermal units (499.57 dd's) according to Ismail *et al.*, (2005) for completion of *E. insulana* winter generation was taken as basis for accurating time of the real peaks occurrence of the winter generations during the three tested seasons (1998, 1999 and 2000) at the two Governorates under study. The results obtained could be presented as follows:

3. Fayoum Governorate

As shown in Table (1) and Fig. (1) the data indicated that the observed and expected peaks of winter generation occurred at June 11th, June 8th and June 14th when the accumulated thermal units reached 504.8, 502.5 and 510.5 dd's where the average number of captured male moths were 7.6, 5.0 and 9.4 males for 1998, 1999 and 2000 cotton seasons, respectively.

TABLE (I)

Comparison of observed and expected *E. insulana* generations by monitoring sex pheromone traps and accumulated degree-days (dd's) at Fayoum Governorate during 1998, 1999 and 2000 cotton seasons.

Seasons	Generations	Generation dates		Deviation (days)	Accumulated degree-days (dd's)
		Observed	Expected		
1998	Winter	11/6	11/6	0	504.8
	1st	11/7	6/7	+5	508.8
	2nd	4/8	30/7	+5	514.2
	3rd	28/8	21/8	+7	499.8
	Average			+4.25	507.0
1999	Winter	8/6	8/6	0	502.5
	1st	5/7	3/7	+2	490.4
	2nd	1/8	29/7	+3	503.5
	3rd	25/8	25/8	0	509.0
	Average			+1.25	501.4
2000	Winter	14/6	14/6	0	510.5
	1st	11/7	10/7	+1	504.4
	2nd	1/8	3/8	-2	510.0
	3rd	28/8	29/8	-1	497.5
	Average			-0.5	505.6

The peak of the first generation occurred on July 11th for 1998 and 2000 with an average of 23.6 and 15.4 males, whereas this peak appeared on July 5th with average 19.0 males for 1999 season. The expected dates were July 6th, July 3rd and July 10th and appeared with 5, 2 and 1 days earlier after accumulation of 508.8, 490.4 and 504.4 dd's during 1998, 1999 and 2000, respectively. Concerning the 2nd generation, the actual observed peaks occurred on Aug. 4th with an average of 29.0 males (1998), and on Aug. 1st for both 1999 and 2000 with an average of 26.6 and 21.6 males, while the corresponding expected date were July 30th, July 29th and Aug.3rd with deviation intervals 5 and 3 days earlier and 2 days later when completed 514.2, 503.5 and 510.0 dd's for the three successive seasons, respectively.

The male moths emergence of the 3^{rd} generation, *i.e.*, the actual observed peak which represented the highest average number of captured male moths appeared on Aug. 28^{th} for 1998 and 2000 and on Aug.25^{th} for 1999, where the average numbers were 37.0, 14.0 and 24.4 males for the three seasons, respectively. The expected peaks occurred 7 days earlier, zero day and only one day later for tested cotton seasons, respectively.

Data in Table (1) revealed also that there was discrepancy of (0 to 7), (0 to 3) and (-2 to 1) days between observed and expected periods, with an average of 4.25, 1.25 and -0.5 days for the three investigated seasons respectively, while the general discrepancy average reached 1.66 days.

4. Minia Governorate

Data in (Table 2 and Fig.2), show that the observed peaks of the winter generation occurred on June 5^{th} (1998) and June 8^{th} (1999 and 2000) as the accumulated thermal units reached 499.3, 505.8 and 506.6 dd's, the average number of captured moths were 20.0, 24.4 and 18.0 males for 1998, 1999 and 2000 cotton seasons, respectively. The expected peak for this generation occurred at the same date of observed peak during the three successive seasons.

The three successive generations as expressed by observed peaks could be presented as follows: the 1^{st} observed peak occurred on July 2^{nd}, July 5^{th} and July 8^{th} within an average of 24.0, 32.0 and 23.2 males for 1998, 1999 and 2000, respectively, whereas the corresponding expected dates for that 1^{st} generation, which fixed according to the calculation of thermal units occurred at the same observed dates (July 2^{nd} and July 8^{th}) for 1998 and 2000 and July 6^{th} with one day later for 1999. The expected dates for the 1^{st} generation appeared after accumulation of 497.5, 505.3 and 511.1 dd's during the three successive seasons. Concerning the 2^{nd} generation, the real observed peaks occurred on Aug. 1^{st}, Aug. 7^{th} and Aug. 4^{th} with an average of 37.2, 78.0 and 29.4 males for the three cotton seasons, respectively, while the expected date of these peaks occurred at July 28^{th} and Aug. 2^{nd} with 4 and 5 days earlier when the thermal units completed 498.3 and 501.2 dd's during 1998 and 1999 cotton seasons, respectively, whereas in 2000 this peak occurred at the same observed date (Aug. 4^{th}) when the thermal units completed 512.8 dd's.

The male moths emergence of the 3^{rd} generation, *i.e.*, the actual observed peak which represented the highest average number of captured male moths, appeared on Aug.28^{th}, Sep. 6^{th} and Aug.31^{st}, where the average reached 46.0, 130.4 and 29.2 males for 1998, 1999 and 2000, respectively. The expected peaks of this generation occurred at Aug. 22nd (1998) and Aug.30th (1999 and 2000) with deviation intervals 6, 7 and 1 days earlier as the accumulated degree-days completed 512.2, 497.0 and 514.3 dd's for the three successive seasons, respectively.

Also, data in Table (2) revealed that there was a discrepancy of (0 to 6), (-1 to 7) and (0 to 1) days between observed and expected periods, with average of 2.5, 2.8 and 0.25 days for the three investigated seasons, respectively, while the general calculated average of discrepancy reached 1.85 days.

TABLE (II)

Comparison of observed and expected *E. insulana* generations by monitoring sex pheromone traps and accumulated degree-days (dd's) at Minia Governorate during 1998, 1999 and 2000 cotton seasons.

Seasons	Generation	Generation dates		Deviation (days)	Accumulated degree-days (dd's)
		Observed	Expected		
1998	Winter	5/6	5/6	0	499.3
	1st	2/7	2/7	0	497.5
	2nd	1/8	28/7	+4	498.3
	3rd	28/8	22/8	+6	512.2
	Average			+ 2.5	501.8
1999	Winter	8/6	8/6	0	505.8
	1st	5/7	6/7	-1	505.3
	2nd	7/8	2/8	+5	501.2
	3rd	6/9	30/8	+7	497.0
	Average			+ 2.8	502.3
2000	Winter	8/6	8/6	0	506.6
	1st	8/7	8/7	0	511.1
	2nd	4/8	4/8	0	512.8
	3rd	31/8	30/8	+1	514.3
	Average			+ 0.25	511.2

As shown in Table (3) the general mean of deviation for the two Governorates during the whole period of investigation reached + 1.76 days before real peak occurrence. This leads to good and perfect control and minimized the cost, time, effort and hazard of chemical control, which usually used against this insect.

TABLE (III)

The deviations of expected generations of E. insulana at Fayoum and Minia Governorates during the three tested seasons.

Governorate	Average deviations (days)			Mean (days)
	1998	1999	2000	
Fayoum	+4.25	+1.25	-0.5	+1.66
Minia	+2.5	+2.8	+0.25	+1.85
General mean				+1.76

These results are in agreement with those obtained by Potter *et al.*, 1981 on *H. virescens*; Richmond *et al.*, 1983 on *Rhvacionia frustrana* and Moftah *et al.*, 1988 on *P. gossypiella*, who stated that the negligible values of the difference between actual and predicted values of thermal units and the corresponding developmental times of this insect generation, which indicate the accurate simulation of the relationship between temperature and development under field conditions.

From the economic point of view, these results would reduce efforts and costs of *E. insulana* control by monitoring its population level in cotton fields by using simply allowing checking of sex pheromone trap catches at certain periods. Also, it is better for good prediction when the period between predicted dates and observed ones has been as short as possible where the plant protection decision makers could be ready enough to start this control action before observed peaks occurred. The accuracy of prediction according to DD's and population patterns of *E. insulana* in particular district should enable growers and pest control advisors to reduce the monitoring period by allowing checking of sex pheromone traps on critical period which leads to expect the infestation in green bolls, hence, accurate the timing of control in proper time. This should also minimize generally the costs and the hazard of chemical control. However, the improvement of the synthetic sex pheromone of the *E. insulana* during the last few years, has offered a successful tool for studying the changes in the population of this insect, which leads to study the determination of spiny bollworm generations.

Monitoring procedures start from May, which leads to achieve the threshold infestation level in cotton plants, green bolls, thus accurating the proper time for control measurements and subsequently minimize the final costs.

Generally, it is worthy to mention out here that determination of the developmental threshold and the accumulated thermal units (DD's) required to complete insect life – cycle should have value in prediction of cotton infestation by determining accumulated degree-days for Fayoum and Minia Governorates. The expected peaks and the corresponding expected generations for spiny bollworm could be helpful when I.P.M. control tactics are considered.

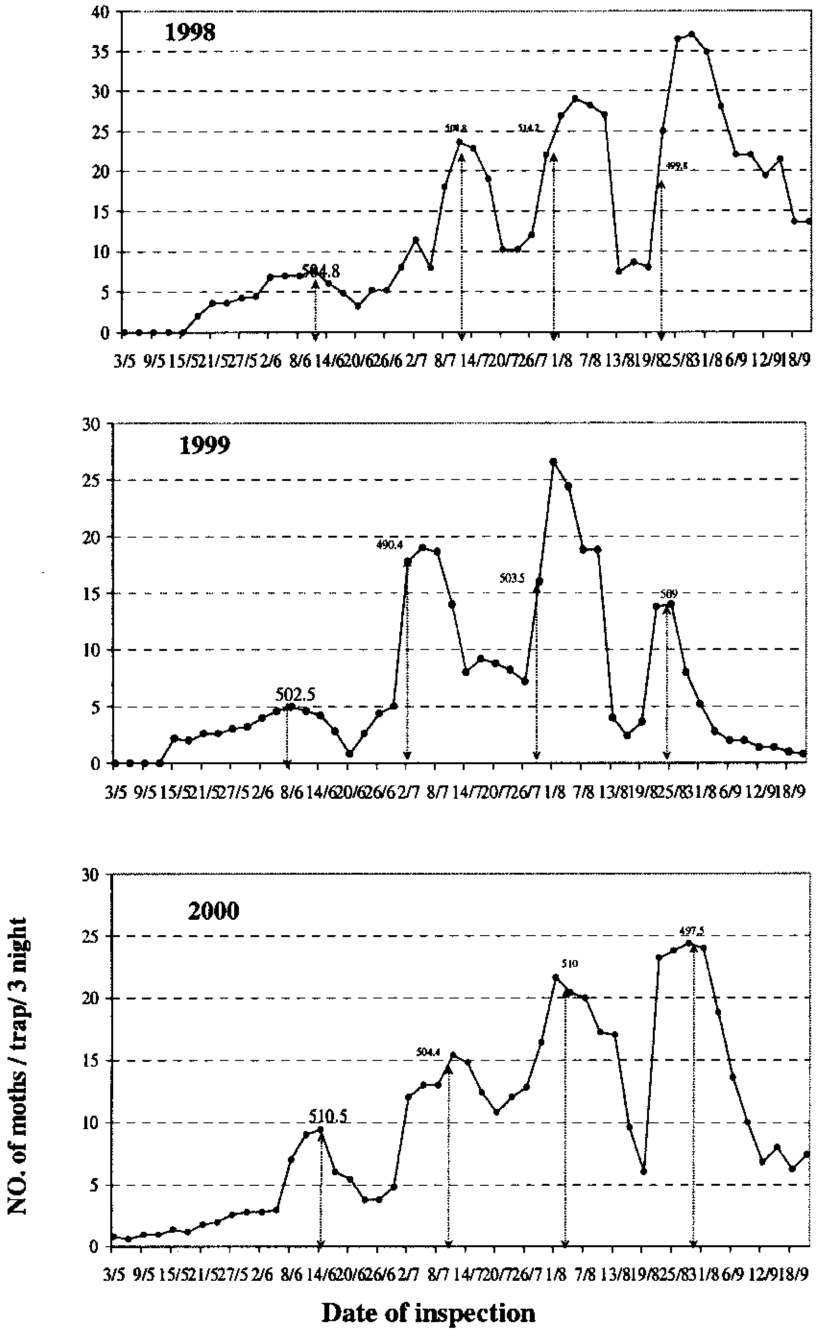

Fig (1): Deviation between observed and expected annual generations of *E. insulan* at Fayoum Governorate 1998, 1999 and 2000 cotton seasons.

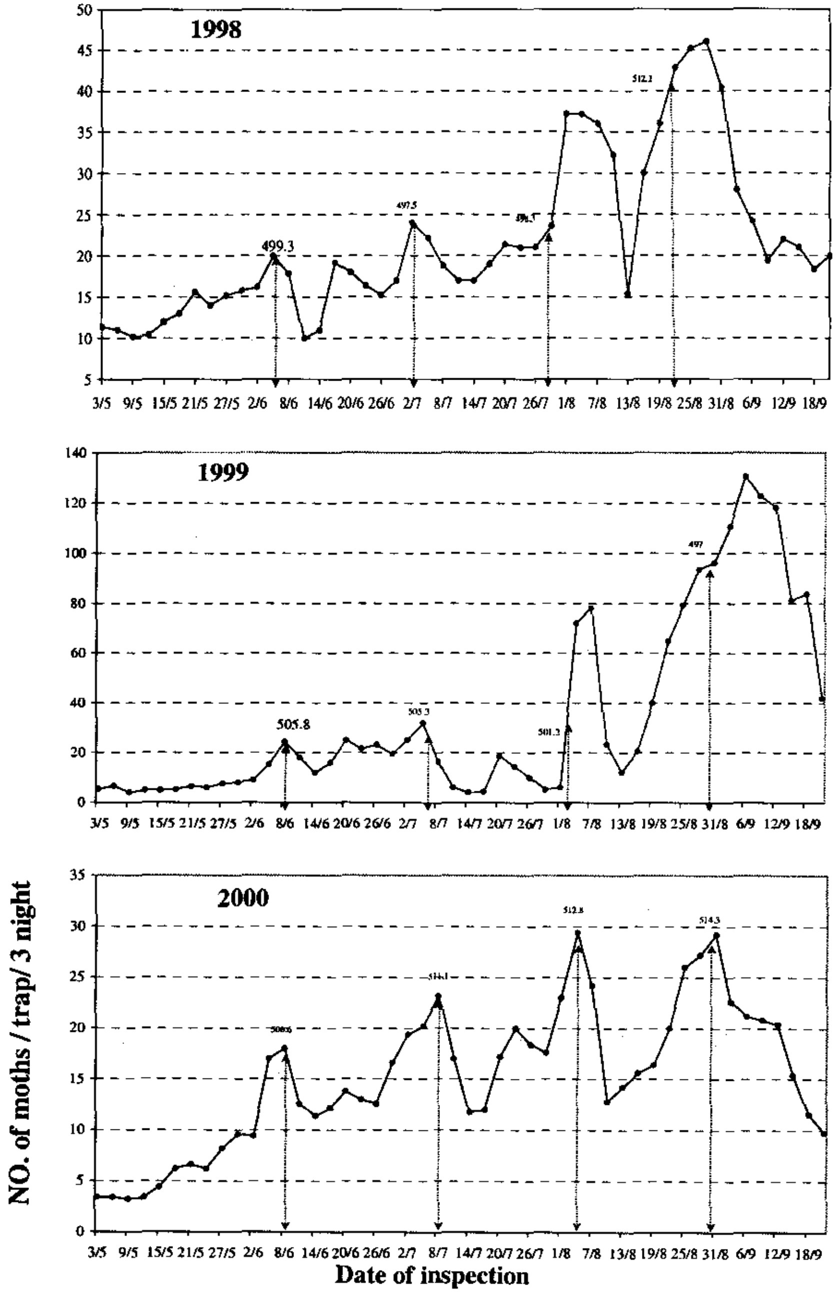

Fig (2): Deviation between observed and expected annual generations of *E. insulana* at Minia Governorate during 1998, 1999 and 2000 cotton seasons

SUMMARY

The temperature is an important environmental factor on rate of development, survival and any other biological and ecological aspects for the *Earias insulana*. Seasonal abundance of the insect population and prediction of field generation throw a light on the temperature influence on development in the field. The present work was conducted at Fayoum and Minia Governorates, for three successive cotton seasons (1998, 1999 and 2000) using the sex pheromone traps (funnel trap) for studying the seasonal variability and prediction possibility of the *E. insulana* adult population in relation to heat unit accumulations. Data revealed that the three main generations were observed in cotton fields in addition to the winter generation during the three successive seasons at the two Governorates. The results cleared that the mean deviation between the observed and expected generations were +4.25, +1.25 and -0.5 days with an average of +1.66 days at Fayoum Governorate, while they were +2.5, +2.8 and +0.25 days with an average of +1.85 days at Minia Governorate The data reveled that the general mean deviation between observed and expected peaks was +1.76 days for the three seasons at the two Governorates. The expected peaks and the corresponding expected generations for the spiny bollworm could be helpful when I.P.M. control tactics are considered.

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