PREDICTING THE ANNUAL GENERATIONS OF THE SPINY BOLLWORM *EARIAS INSULANA* (BOISD.) (LEPIDOPTERA: ARCTIIDAE) BY SEX PHEROMONE TRAP CATCHES AND HEAT UNIT ACCUMULATIONS AT DELTA REGION

ISMAIL I. ISMAIL[1]; MOHAMED Y. HASHEM[1]; SAID A. EMARA[2] AND HASSAN F. DAHI[2]

[1]*Econ. Entomol. and Pesticides Dept.; Fac., Agric., Cairo Univ., Giza, Egypt.*

[2]*Plant Protec. Res. Inst., ARC, Dokki, Giza, Egypt*

(Received 23-4-2007)

INTRODUCTION

It is a well-known fact that Semiochemicals in general, and pheromones in particular, proved to be an important new tool for insect pest management with many advantages over conventional methods (Taman, 1990).

Accurant forecasting with pheromone traps and usage of pheromone in mass - trapping and mating - disruption can reduce the dependence on insecticides and be involved among the IPM programs, which help to avoid the problems of environmental pollution, destruction of natural predators and parasitoids and build-up of insect resistance by over use of insecticides. Clement *et al.* (1979) mentioned that the pheromone traps appeared to be more sensitive than light traps in monitoring early season occurrence of *Agrotis ipsilon* males.

On the other hand, temperature is the ever present factor influencing insect life and the relationship between the insect activity and this factor may be utilized to gain some insight into the size and behavior of field population and consequently into life history and ultimately prediction of future generation (Riedle *et al.*, 1976; Sevacherian *et al.*, 1977). Seasonal abundance and heat requirements for lepidopterous insect pests were studied (Davidson 1944; Potter *et al.*, 1981; Moftah *et al.*, 1988; Hashem *et al.*, 1997; Emara *et al.*, 1999 and Ismail *et al.*, 2005).

In addition, the knowledge on the role of temperature summations is one of the best and new approaches toward eventual economical control by providing early-warning system for the insect abundance and the population fluctuation of spiny bollworm *Earias insulana*.

The goal of this work is to clarify the influence of 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 reduce monitoring time and timing control measures on cotton fields.

MATERIAL AND METHODS

This work was conducted at Aga and Menouf districts at Dakahlia and Menoufia 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 is containing 1 mg. of the active ingredient of the specific pheromone for *Earias insulana*, according to 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, as described by Flint and Merkle (1983).

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 89. 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 catches of *Earias insulana* males were collected, counted, identified and recorded every 3 days.

Daily maximum and minimum temperatures were obtained and recorded by 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;

$$HJ = \begin{cases} (\text{max.} + \text{min.}/2\text{-}C, & \text{if max.}>C \ \&\ \text{min.}>C. \\ (\text{max.} - C)2/(\text{max.} - \text{min.}), & \text{if max.}>C \ \&\ \text{min}<C. \\ 0 & \text{if max.} <C \ \&\ \text{min.}<C. \end{cases}$$

C = threshold temperature.

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.

RESULTS AND DISCUSSION

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 generations could be estimated.

Three main generations of the spiny bollworm, *E. insulana* were observed in cotton fields 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.

Mabrouk (1967) reported that the increasing of spiny bollworm moths in cotton fields (as indicated by sex pheromone traps) indicated that the main activity of this insect concentrated mainly in cotton field while the summer maize was free of infestation.

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

1. Dakahlia Governorate

As shown in Table (1) and Fig. (1), the observed and expected peaks of the winter generation (which presented the 1^{st} annual generation) occurred at June 5^{th}, 5^{th} and 11^{th} at 498.3, 499.7 and 497.5 dd's where the maximum average number of captured moths were 16.6, 6.6 and 9.2 males for cotton seasons 1998,1999 and 2000, respectively.

TABLE (I)

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

Seasons	Generations	Generation dates		Deviation (days)	Accumulated degree-days (dd's)
		Observed	Expected		
1998	Winter	5/6	5/6	0	498.3
	1^{st}	5/7	4/7	+1	495.1
	2^{nd}	1/8	1/8	0	490.1
	3^{rd}	31/8	26/8	+5	490.9
	Average			+ 1.5	493.6
1999	Winter	5/6	5/6	0	499.7
	1^{st}	5/7	4/7	+1	509.3
	2^{nd}	1/8	30/7	+2	496.6
	3^{rd}	3/9	29/8	+5	505.2
	Average			+ 2.0	502.7
2000	Winter	11/6	11/6	0	497.5
	1^{st}	11/7	8/7	+3	503.0
	2^{nd}	4/8	3/8	+1	492.3
	3^{rd}	28/8	29/8	-1	497.4
	Average			+ 0.75	497.6

Three successive generations (observed generations) appeared after the winter generation during the three seasons of investigation. The 1^{st} peak occurred on July 5^{th} within average of 43.2 and 10.0 males for 1998 and 1999. Whereas this peak appeared on July 11^{th} (average 25.4 males) for the third cotton season. The expected dates were July 4^{th}, July 4^{th} and July 8^{th} at 495.1, 509.3 and 503.0 dd's for 1998, 1999 and 2000, respectively. For the 2^{nd}generation, the actual observed peaks occurred on Aug.1^{st} during 1998 and 1999 with an average of 62.0 and 13.4 males for each, while it occurred on Aug. 4^{th} (27.8 males) during 2000, whereas the expected date of these peaks were Aug.1^{st}, July 30^{th} and Aug.3^{rd} when completed 490.1, 496.6 and 492.3 dd's for 1998,1999 and 2000, respectively. As for actual observed peaks of the 3^{rd} generation which represented the highest average number of captured male moths, the peaks appeared on Aug.31^{st}, Sep.3^{rd} and Aug.28^{th} for the three successive seasons, where the average mean numbers were 45, 11.2 and

26.5 males, respectively. Concerning the corresponding dates of expected peaks of the four generations, the results presented and illustrated in the above mentioned Table and Figures show that the 1st generation was one day earlier for 1998 and 1999, 3 days earlier for 2000, while it was zero day in the case of 2nd generation during 1998 and 2 & 1days earlier for 1999 & 2000. The expected date of the 3rd peak was 5 days earlier for 1998 and 1999, and only one day later for 2000.

The data in Table (1) revealed also that there was discrepancy of (0 to 5), (0 to 5) and (-1 to 3) days between observed and expected period, with an average of 1.5, 2.0 and 0.75 days for the three investigated seasons, 1998, 1999 and 2000, respectively.

2. Menoufia Governorate

As shown in Table (2) and Fig. (2), the observed peaks of the winter generation (in which the male moths emerged from the winter brood) occurred on May 30th, June 2nd and May 27th which appeared after accumulation of 501.8, 498.9 and 503.9 dd's during 1998, 1999 and 2000, respectively. Accordingly, the expected peaks appeared on the same date of observed peaks throughout the three seasons.

In 1998 season, the 1st observed generation on cotton field appeared on June 29th and the expected one occurred also at the same date as the thermal units accumulation completed 492.0dd's. The peaks of the same generation (observed & expected) occurred at (2nd & 3rd of July and (26th & 28th of June with one and two days later when the thermal units accumulation completed 494.9 and 509.5dd's at 1999 and 2000.

Concerning the 2nd generation, the observed peaks occurred on July 26th 1998, Aug.1st 1999 and July 29th 2000, while the expected ones appeared one day earlier, one day later and two days earlier with thermal units 503.1, 494.7 and 499.2 dd's for 1998, 1999 and 2000, respectively. The emergence of the 3rd generation males reached their real (observed) peaks on Aug. 25th and Sept.3rd, while the corresponding expected peaks of this generation occurred 5 and 3 days earlier when the thermal units accumulated 499.8 and 495.6 dd's for 1998 and 1999, respectively, whereas the same generation at season 2000 show another trend when the observed and expected generation appeared at the same date (Aug.25th) with 502.8dd's.

On the other hand, results in Table (2) indicated that there was a discrepancy of (0 to 5), (-1 to 3) and (-2 to 2) days between observed and expected period with an average of 1.5, 0.25 and 0.0 days for the three tested seasons, respectively, while general calculated average reach +0.58 days which indicate that the predicting matter was highly significant and accurate.

TABLE (II)

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

Seasons	Generations	Generation dates		Deviation (days)	Accumulated degree-days (dd's)
		Observed	Expected		
1998	Winter	30/5	30/5	0	501.8
	1st	29/6	29/6	0	492.0
	2nd	26/7	25/7	+1	503.1
	3rd	25/8	20/8	+5	499.8
	Average			+1.5	**499.0**
1999	Winter	2/6	2/6	0	498.9
	1st	2/7	3/7	-1	494.9
	2nd	1/8	2/8	-1	494.7
	3rd	3/9	31/8	+3	495.6
	Average			+0.25	**496.0**
2000	Winter	27/5	27/5	0	503.9
	1st	26/6	28/6	-2	506.5
	2nd	29/7	27/7	+2	499.2
	3rd	25/8	25/8	0	502.8
	Average			0.0	**503.1**

As shown in Table (3) the general mean of deviation for the two Governorates during the whole period of investigation reached + 1.0 day before occurrence of the real peak. This leads to good and perfect control and minimized the cost, time, effort and hazard of chemical control, which usually used against this insect.

These results are in agreement with those obtained by Clement *et al.* (1979) on *A. ipsilon*; Potter *et al.* (1981) on *Heliothis virescens*; Richmond *et al.* (1983) on *Rhvacionia frustrana* and Moftah *et al.* (1988) on *Pectinophora 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 generations, indicate the accurate simulation of the relationship between temperature and development under field conditions. Also, several authors studied the role of environmental factors and the thermal units accumulations (dd's) as a mean for forecasting moth population peaks *e.g.* Chu and hennebrry (1992) on *P. gossypiella,* Korat and Lingappa (1995) on some bollworm moths (*P. gossypiella, E. insulana and H. armigera*); Emara *et al.* (1999) on *Spodoptera littoralis* and Al Beltagy (1999) on *E. insulana.*

TABLE (III)

The deviations of expected generations of *E. insulana* at Dakahlia and Menoufia Governorates during the three tested seasons.

Governorate	Average deviations (days)			Mean (days)
	1998	1999	2000	
Dakahlia	**+1.5**	**+2.0**	**+0.75**	**+1.41**
Menoufia	**+1.5**	**+0.25**	**0.0**	**+0.58**
Mean				**1.0**

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 design makers could be ready enough to start this insect control programme 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 using sex pheromone traps on critical period which leads to expect the infestation in green bolls, hence, timing of control in the proper time. This should also minimize generally the costs and the hazards 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 determination of spiny bollworm generations.

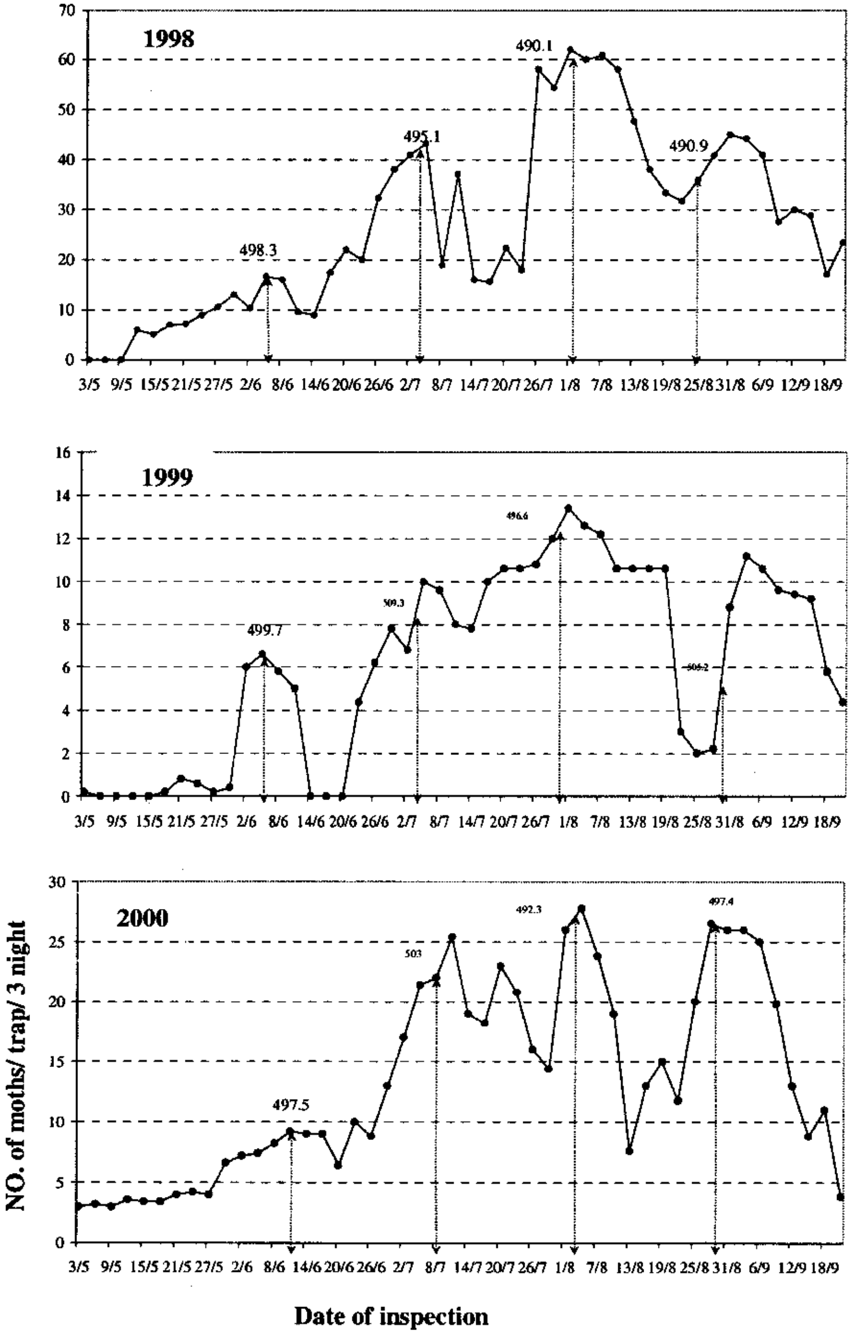
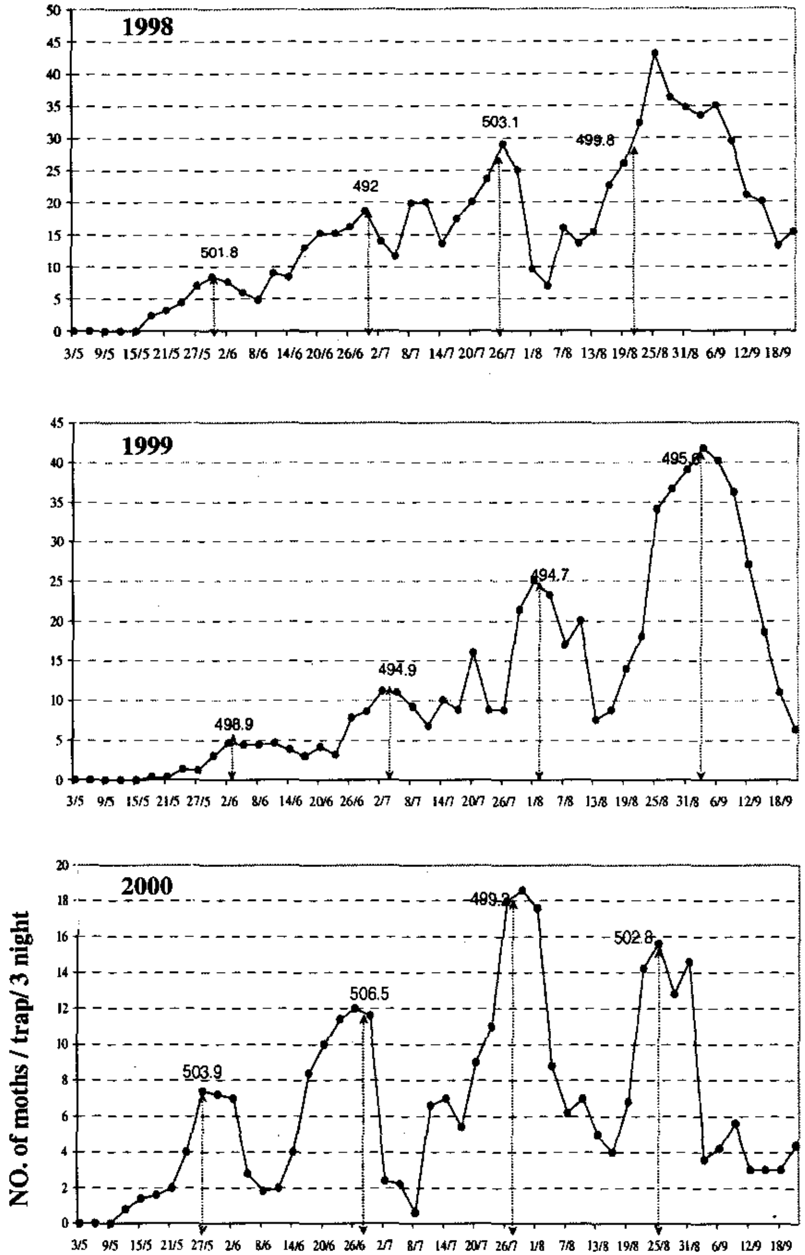


Fig (1): Deviation between observed and expected annual generations of *E. insulana* at Dakahlia Governorate during 1998, 1999 and 2000 cotton seasons.



Date of inspection

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

SUMMARY

The present work was conducted at Dakahlia and Menoufia 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 *Earias insulana* adult generations in relation to heat unit accumulations. The temperature is an important environmental factor on rate of development, survival and any other biological and ecological aspects of *E. insulana*. Seasonal abundance of the insect population and prediction of field generation shed light on the temperature influence on development in the field. 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 1.5, 2.0 and 0.75 days with an average of 1.4 days at Dakahlia Governorate, while they were 1.5, 0.25 and 0.0 days with an average of 0.58 day at Menoufia Governorate. The data reveled that the general mean deviation between observed and expected peaks was +1.00 day 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.

REFERENCES

AL-BELTAGY, A. M. (1999): Heat unit accumulations for forecasting spiny bollworm, *Earias insulana* (Boisd.), population dynamics and density on cotton. *(The 2nd Int. Conf. of Pest Control, Mansoura, Egypt; 737-744).*

CHU, C. C. and T. J. HENNEBERRY (1992): Pink bollworm (Lepidoptera: Gelechiidae), male moth trap catches in gossyplure-baited traps in relation to accumulated heat units. *(Southwestern Entomologist, 17 (2): 79-86).*

CLEMENT, S. L.; E LEVINE and R. W. RINGS (1979): Population trends of the black cutworm correlated with thermal units accumulations. *(IX Int. Cong. Plant Prot. and 71st ann. Meet. Amer. Phytopath. Soc.).*

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

DHAWAN, A. K. and S. A. SIDHU (1988): Effect of location of gossyplure traps on catches of pink bollworm, *Pectinophora gossypiella* (Saund.) males. *(J. Insect. Sci., 1(2): 136-141).*

EMARA, S. A.; M. Y. HASHEM; I. I. ISMAIL and H. F. DAHI (1999): Impact of heat units required for the development of cotton leafworm, *Spodoptera littoralis* (Boisd.) on its seasonal flactuations and annual generations. *(2nd Inter. Conf. Pest Control, Mansoura., 759 : 771).*

FLINT, H. M. and J. R. MERKLE (1983): Methods for efficient use of the Delta trap in the capture of pink bollworm moths, *Pectinophora gossypiella. (Southwestern Entomologist, 8 (2): 140-144).*

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. Ent. Soc. Egypt, 75: 140-151).*

HALL, D. R.; P. S. BEEVOR; R. LESER and B. F. NESBIT (1980): (E, E) 10, 12 Hexadecadiennal: a component of the female sex pheromone of spiny bollworm *Earias insulana* (Boisd.) (Lepidoptera: Noctuidae). *(Experimentia, 36: 152 – 154).*

HUMMEL, H. E.; L.K. GASTON; H. H. Horey; R. S. Kaae; K. S.BYRNE and R. M. SILVERTEIN (1973): Classification of the chimical status of the pink bollworm sex pheromone. *(Science (Wash. D.C.), 181: 873-875).*

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. Ent. Soc. Egypt, 82: 255- 265).*

KORAT, D. M. and S. LINGAPPA (1995): Influence of weather factors on the pheromone trap caches of corn bollworm moths.Ind. *(J. plant prot., 23(2) : 188-190).*

Mabrouk, A. A. M. (1967): Biological and ecological studies on *Earias insulana* (Boisd.). *(Unpublished M.Sc. Thesis, Fac. Agric. Cairo Univ).*

MOFTAH, E.A.; A. M. YOUNIS; M. F. GIRGIS and A. A. KHIDR (1988): Thermal requirements and prediction models for pink bollworm *Pectinophora gossypiella* (Saund.). *(Menia J. Agric. Res. & Dev., 10 (4): 1563-1573).*

POTTER, M. F.; R. T. Huner and T. F. Waston (1981): Heat unit requirements for emergence of overwintering tobacco budworm, *Heliothis virescense* (F.), in Arizona. *(Envirom. Entomol., 10: 543-545).*

RASHAD, A. M. (1981): Studies on the attraction of male moths of *Pectinophora gossypiella* (Saund.) (Lepidoptera: Gelechiidae) to the sex pheromone. *(Unpublished Ph.D. Thesis, Fac. Agric. Cairo University, 88 pp).*

RICHMOND, J. A.; H. A. THOMAS and H. B. HATTACHARGYA (1983): Predicting spring flight of nantucket pine tip moth (Lepidoptera: Olethreutidae) by heat unit accumulation. *(J. Econ. Entomol., 76: 269-271).*

RIEDL, H.; B. A. CROFT and A. J. HOWITT (1976). Forecasting codling moth phenology based on pheromone trap catches physiological-time models. *(Canad. Entomol., 108: 449 – 460).*

SEVACHERIAN, V.; N. C. TOSCANO; R. A. VAN STEENWYK; R. K. SHARMA and R. R. SANDERS (1977): Forecasting pink bollworm emergence by thermal Summation. *(Environ. Entomol., 6 (4): 545 – 546).*

TAMAN, F. A. (1990): Pheromone trapping of cotton insects in relation to some climatic factors. *(Alex. Sci. Exch., 11 (3): 37-53).*