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DEVELOPMENTAL THRESHOLDS AND THERMAL REQUIREMENTS NEEDED FOR SOME AGRO-ECOSYSTEM STRAINS OF CERTAIN PESTS INHABITING COTTON FIELDS:
2- SPINY BOLLWORM, *Earias insulana* (BOISD.) [NOCTUIDAE]

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ABSTRACT

A laboratory experiment was conducted to estimate the developmental threshold for immature stages of the spiny bollworm, *Earias insulana* (Boisd.) and the accumulated thermal units needed for completion of one generation. Eggs from different Agro-ecosystems viz. Qalyubyia, Sharkia and Minia Governorates were subjected to the present experiment in addition to a laboratory strain.

Obtained results ,reveal that egg developmental period was greatly affected by rearing temperature. At 20°C, eggs from Qalyubyia strain developed faster as compared to other field strains. At 30°C, eggs of the laboratory and field strains developed at a range of 2.8-3.0 days. The lower thresholds of egg were 7.55, 7.59 and 10.57°C for Sharkia, Qalyubyia and Minia, respectively, while thermal units needed for eggs to hatch were 64.69, 60.61 and 54.05 DDs.

Larvae of the laboratory strain were faster in development than others of different Agro-ecosystems. At 25°C, larval duration lasted for 14.5±1.15 days for the laboratory strain while it ranged between 16-18 days for the field strains. The developmental threshold did not significantly differ between the tested governorates since it ranged between 11.02°C and 12.39°C. Thermal constants, however were higher for Minia strain (277.78DDs) followed by Sharkia (243.90 DDs), Qalyubyia (238.09 DDs) and laboratory strain (227.27 DDs).

Pupae of the laboratory strain developed faster than those reared from different Agro-ecosystems. At 25 and 30°C, pupae from Sharkia and Qalyubyia eco-types developed faster than those of Minia Governorate. The zero of development values were very close, it ranged between 10.26 and 11.06°C. Thermal requirements were 181.82 DDs for Minia and laboratory strains, 168.08 DDs for Qalyubyia and 222.22 for Sharkia strain.

Since females resulted from eggs collected from different Agro-ecosystems and fed as larvae on an artificial diet failed to lay eggs after mating, so the pre-oviposition period was estimated for females resulted from laboratory strain only. This period ranged between 4.33±0.50 and 2.30±0.48 days at 20°C and 30°C, respectively. The zero of development for this period was 9.17°C and the thermal requirements estimated were 49.02 DDs.

The whole generation duration for the laboratory strain was 61.18, 33.80 and 27.97 days at 20, 25 and 30°C respectively. The zero of development for the whole generation was estimated as 11.04°C, while the amount of thermal units needed for completing one generation were 512.82 DDs.

Keywords: *Earias insulana*, spiny bollworm, biofeatures, developmental threshold, zero of development, heat units, agroecosystem.

INTRODUCTION

The spiny bollfworm, *Earias insulana* (Boisd.) is a serious pest on cotton and other cultivated plants allover Egypt. The larvae attack cotton bolls, the Egyptian mallow, okra and Roselle (Karkadeh) (El-Mezayen, *et al.* 1997). Taher (1983) and El-Zanan (1987) found that the duration of each stage for this pest depended mainly on temperature. They also noticed that the pest developed successfully at temperature ranged from 15 to 31°C. An integrated pest management program involves a total system to suppress the pest population and depends on predicting the seasonal populations cycles of insects. This has led to the formulation of many mathematical models (Clement *et al.* 1979; Richmond *et al.* 1983 and Pedigo, 1991). Because demography was developed for human populations, the basic unit of time in most studies is the day or some multiple (e.g. month, year). However, the use of calendar time is not particularly appropriate for insects or other poikilotherms that are unable to maintain stable core body temperature (Southwood, 1978 and Taylor, 1979). Although, certain insects can increase or decrease their body temperature from ambient temperature, in general, the rate of insect development is predictable across a reasonable range of temperatures using heat accumulations (degree-days or physiological time). These facts suggest that a demographic analysis based on degree-days may provide a level of predictability for field populations that constant temperature laboratory studies on a calendar date basis are unable to provide (Jcnes *et al.*, 1997). Several methods are available for calculating °D. From the simplest to the most complicated, these include (1) the max + min method; (2) the "saw-tooth" or trapezoidal approximation; (3) the single sine and (4) the double sine. All of these are called linear methods because rate of development is presumed to be linear with temperature (Wilson and Barnett, 1973). The available literature reveals that little work has been done on the use of temperature accumulation as an aid in forecasting the various stages of insects (Arnold, 1960; Allen, 1976 and Sevacherian *et al.* 1976). The present study is aiming to estimate the time needed for the total developmental stages of the spiny bollworm to complete considering the corresponding thermal units required for completing one generation for this insect ecotypes collected as larvae from different agro-ecosystems namely, Minia, Sharkia and Qalyubyia.

MATERIAL AND METHODS

Large numbers of *Earias insulana* Boisd. larvae were collected from cotton fields in Qalyubyia, Sharkia and Minia Governorates during 2001. Larvae were kept in the laboratory until pupation and adult emergence in addition to the pure strain reared in the Laboratory of Ecological Studies, Department of Plant Protection, Faculty of Agriculture, Ain Shams University. Couples of adults (5 males and 5 females) were kept under glass lamps for mating and were followed up daily for collecting the deposited eggs for each Governorate separately. Newly deposited eggs were incubated at three temperatures, viz.; 20, 25 and 30°C and 80±5 R.H. and was observed twice a day until 50% of hatching and the time required for the development of egg stage was recorded. Larvae were kept in glass vials and fed on an artificial diet proposed by Abdel-Hafez *et al.* (1982). The duration of each larval instar was calculated and newly formed pupae were separated daily. Pupae were kept on the same temperatures until moth emergence and duration of pupal stage was also determined. Resulted moths were sexed and each 5 pairs of moths were kept under glass lamps for mating. Preoviposition period was estimated and deposited eggs were collected daily and kept on the selected rearing temperatures for laboratory strain only since the majority of mated females from different Governorates failed to lay eggs in the laboratory.

Estimates of lower threshold limit for immature developmental stages (t_o) and developmental time needed in days and degree-days were completed by simply adopting methods of Campbell *et al.* (1974). The upper threshold limit was estimated using linear regression equation; $\mathbf{Y = a + bx}$, where Y is the rate of development at temperature x, a and b are the regression constant values. The threshold in this equation is the value of x when Y=zero (Park, 1988). Thermal units (TU) required for the development of each stage were calculated according to the equation of Madubimyi and Koehler (1974); $\mathbf{TU = T\ (t - t_o)}$, where T = developmental period in days at temperature t, t = exposure temperature (°C) and t_o = temperature threshold.

Certain statistical analyses were worked out between the three tested temperatures and the investigated eco-types (Governorates). The interaction between temperatures and the eco-type strains was estimated. Duncan's values were adopted to arrange the successive means of temperatures in different groups.

RESULTS AND DISCUSSION

1) Egg stage:

The egg developmental period varied greatly between laboratory and field strains according to the incubation temperature (F = 436.265**, LSD = 0.1735) and the tested Agro-ecosystem (F = 4.63*, LSD = 0.2003). When eggs were reared on the three tested temperatures viz. 20, 25 and 30°C, the eggs produced from Qalyubyia strain was developed faster than the other three strains. At 20°C, the incubation period was 5.2±0.42 days for Qalyubyia strain and 5.8±0.42 days for Minia strain (Table 1). The duration of Minia strain was also the longest when eggs were incubated at 25°C (3.67±0.42 days). On 30°C, the laboratory and field strains developed almost at the same rate ranged between 2.8-3.0 days (Table 1).

Data presented in Table (2) and graphically illustrated in Fig. (1) reveal that great differences were found between developmental thresholds and thermal requirements between the different ecotypes of spiny bollworm. The lowest threshold zero and as a result the highest accumulation of heat units was obtained for laboratory strain (7.32°C and 66.23 DDs), while the estimated zero of development values for other strains were 7.55, 7.59 and 10.57°C for Sharkia, Qalyubyia and Minia strains respectively.

Table (1): Duration of different developmental stages (in days) for *E. insulana* inhabited different Agro-ecosystems reared on an artificial diet at different temperatures

Stage	Lab. Strain			Qalyubyia			Sharkia			Minia		
	20°C	25°C	30°C	20°C	25°C	30°C	20°C	25°C	30°C	20°C	25°C	30°C
Eggs	5.50±0.52	3.50±0.52	3.00±0.00	5.20±0.42	3.23±0.42	2.80±0.42	5.60±0.52	3.40±0.52	3.00±0.00	5.80±0.42	3.67±0.50	2.80±0.42
Larvae	27.85±3.85	14.5±1.15	12.5±0.93	32.78±4.01	16.63±2.68	13.67±2.32	34.58±2.92	17.71±2.60	14.2±1.71	34.37±3.05	17.56±2.44	15.33±1.62
Pupae	23.50±2.23	12.5±1.01	10.18±1.26	23.91±4.44	14.13±1.74	10.77±1.14	23.93±2.38	14.26±0.97	11.5±1.79	22.77±2.84	13.18±0.85	12.30±1.67
Pre-oviposition	4.33±0.50	3.33±0.48	2.30±0.48	—	—	—	—	—	—	—	—	—
Generation	61.18	33.80	27.97	—	—	—	—	—	—	—	—	—

Table (2): Threshold (zero) of development values and thermal requirements for different developmental stages (in days) for *E. insulana* inhabited different agro-ecosystems reared on an artificial diet at different temperatures

Stage	Lab. Strain		Qalyubyia		Sharkia		Minia	
	Zero of development	Thermal requirements	Zero of development	Thermal requirements	Zero of development	Thermal requirements	Zero of development	Thermal requirements
Eggs	7.32	66.23	7.59	60.61	7.55	64.94	10.57	54.05
Larvae	11.04	227.27	11.98	238.09	12.39	243.90	11.02	277.78
Pupae	11.60	181.81	11.54	196.08	10.26	222.22	11.60	181.82
Pre-oviposition	9.17	49.02	---	---	---	---	---	---
Generation	11.04	512.82	---	---	---	---	---	---

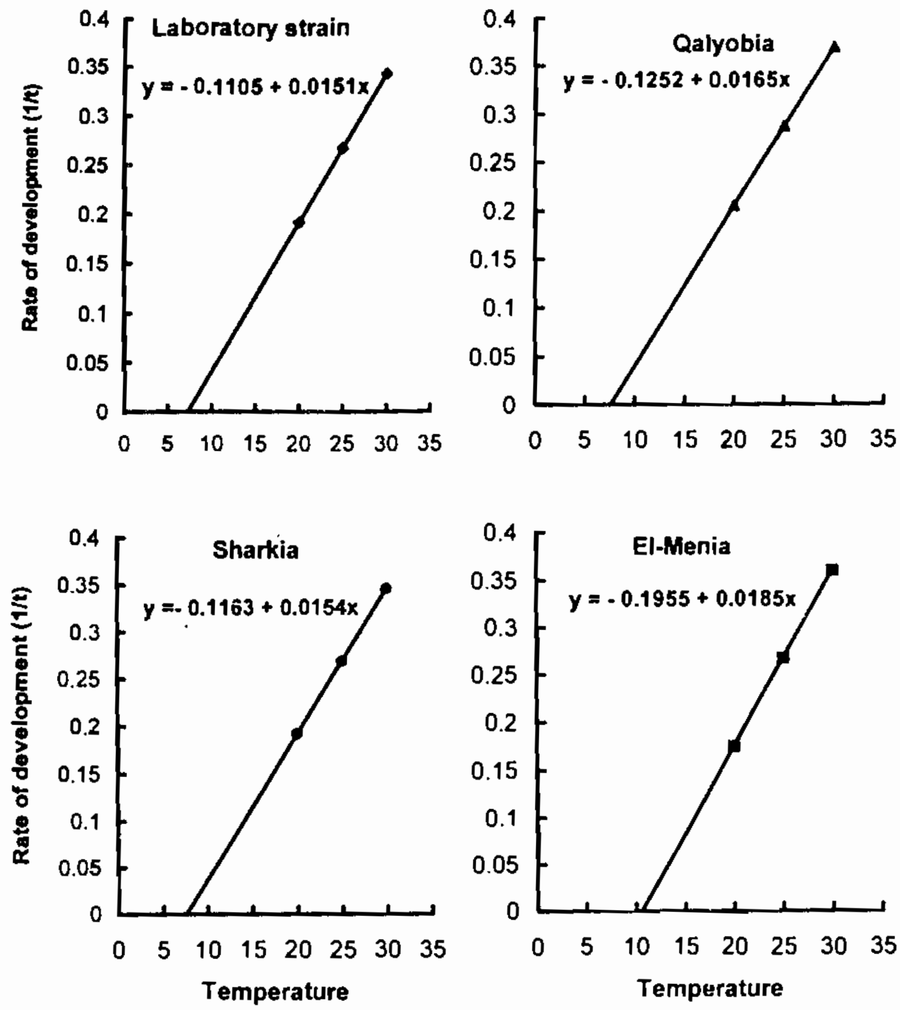

Fig. 1. The regression lines of the relation between developmental rates of *E. insulana* eggs and temperature (laboratory and field strains from different Agro-ecosystems).

The estimated thermal requirements for the later three strains were 64.94, 60.61 and 54.05 DDs. These results are in harmony with those found by Gergis *et al.* (1990) on *Pectinophora gossypiella*.

2) Larval stage:

Data presented in Table (1) and Fig. (2) reveal that duration needed for development of *E. insulana* larvae increases with the decrease in rearing temperature (F = 2577.29***, LSD = 0.4849) and the source of the tested strains (F = 88.175***, LSD = 0.5599). regardless of the rearing temperature, the laboratory strain was faster in development followed by Qalyubyia, Sharkia and Minia strains.

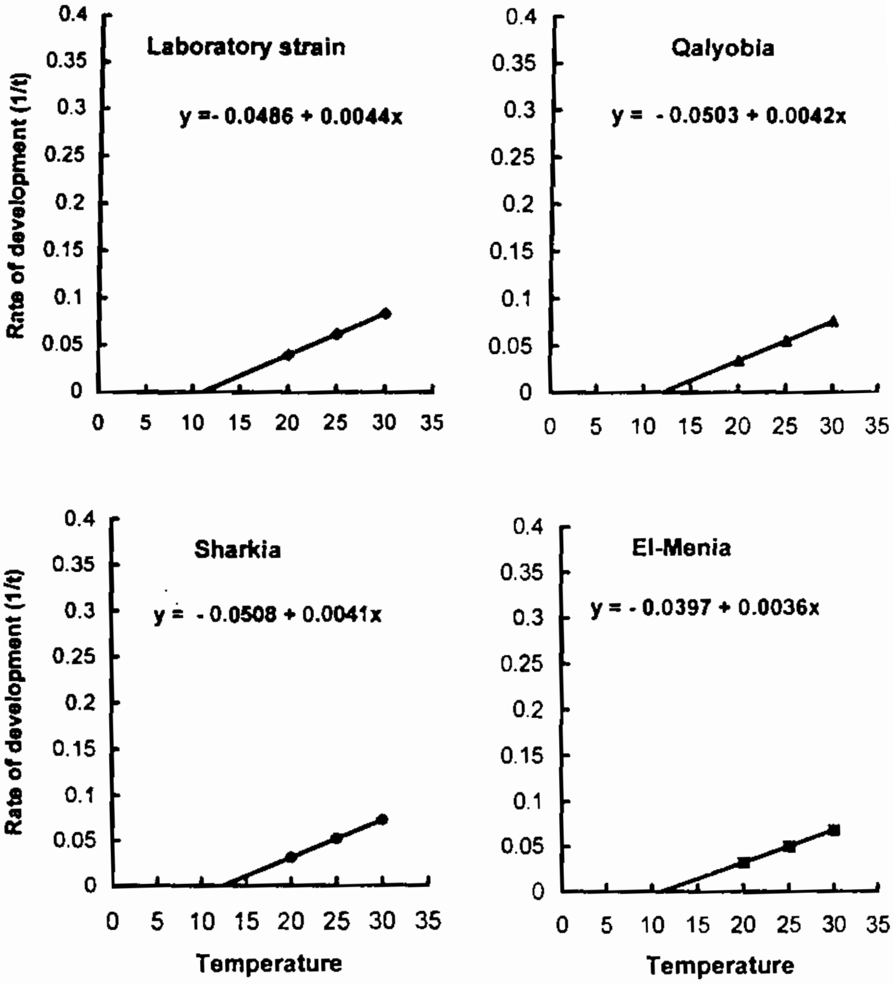

Fig. 2. The regression lines of the relation between developmental rates of *E. insulana* larvae and temperature (laboratory and field strains from different Agro-ecosystems).

At 20°C, the strains were significantly different in development (F = 33.769***, LSD = 1.26). At 25°C, the laboratory strain harbored the shortest duration, i.e. 14.5±1.15 days followed by Qalyubyia (16.63±2.68), Minia (17.56±2.44) which did not differ than that of Sharkia (17.71±2.60). When temperature was raised to 30°C, the situation was the same since the laboratory strain gave the fastest in development per day (0.08/day) followed by Qalyubyia strain (0.073/day), Sharkia strain (0.07/day) and finally, Minia strain (0.065/day).

When the developmental threshold of *E. insulana* larvae was estimated, surprisingly there was no great difference between the different eco-systems, which could be attributed to the nature of the insect infestation since larvae are hiding inside the cotton bolls so the different temperatures in the tested agro-ecosystems had no effect (Table 2 and Fig. 2), 11.02 and 12.39°C were estimated as threshold of development (t_o value) for Minia and Sharkia eco-types, respectively. Conversely, the thermal requirements were the highest for Minia strain (277.78 degree-days); followed by the Sharkia eco-type (243.90 DDs); Qalyubyia strain (238.09 DDs) and finally the laboratory strain that needed only 227.27 DDs. These results are in full agreement with those given by Darwish *et al.* (1989); Li *et al.* (1987) and Wu and Guo (1994) on *Heliothis armigera*

3) Pupal stage:

Data in Table (1) indicate that the duration of the pupal stage was significantly different according to the rearing temperature (F = 1400.38***, LSD = 0.3663) and according to the ecotype (F = 5.541**, LSD = 0.423). Regardless of rearing temperature, the laboratory strain demonstrated the fastest developmental period as compared to those reared from different Agro-ecosystems. For these eco-types, the pupae of Minia developed faster when reared on 20°C, being 22.77±2.84 days; while strains from Sharkia and Qalyubyia did not differ from each other. At 25°C, however, pupae from Sharkia and Qalyubyia eco-types developed in 14.26±0.97 and 14.13±1.74 days; while pupae resulted from larvae and eggs collected from Minia fields were the lowest in development (13.18±0.85 days). The same trend was achieved at 30°C. In general, it appears that pupae from these three Agro-ecosystems did not differ significantly when developmental parameters for each rearing temperature was considered.

It appears from Fig. (3) that zero of development values for pupae resulted from the investigated eco-system fields (Governorates) and the laboratory strain were very close, hence it ranged between 10.26°C for Sharkia and 11.60°C for Minia and laboratory strains. Accordingly, the thermal requirements needed for pupal development were the same for Minia and laboratory strains (181.82 DDs) followed by Qalyubyia (196.08 DDs) and Sharkia strain (222.22 DDs) (Table 2). These results are very close to those obtained by Hutcheson *et al.* (1986) on *P. gossypiella* who mentioned that the lower developmental threshold for pupae reached 12.38°C.

4) Pre-oviposition period:

Since females resulted from eggs collected from different Agro-ecosystems failed to lay eggs after mating, so the pre-oviposition period was estimated for females resulted from laboratory strain only. These periods were 4.33±0.50 and 2.30±0.48 days at 20°C and 30°C, respectively (Table 1). Zero of development for this period was 9.17°C and the thermal requirements estimated were 49.02 DDs (Table 2 and Fig. 4). Taher (1977) indicated that emergence of *E. insulana* adults under 26 and 30°C was much faster than other tested temperatures (mostly because completing their thermal requirements). Younis *et al.* (1988) found the same results when worms were reared on okra pods. Gergis *et al.* (1990) mentioned that the same period in *Pectinophora gossypiella* adults needed 41.84 DDs to complete.

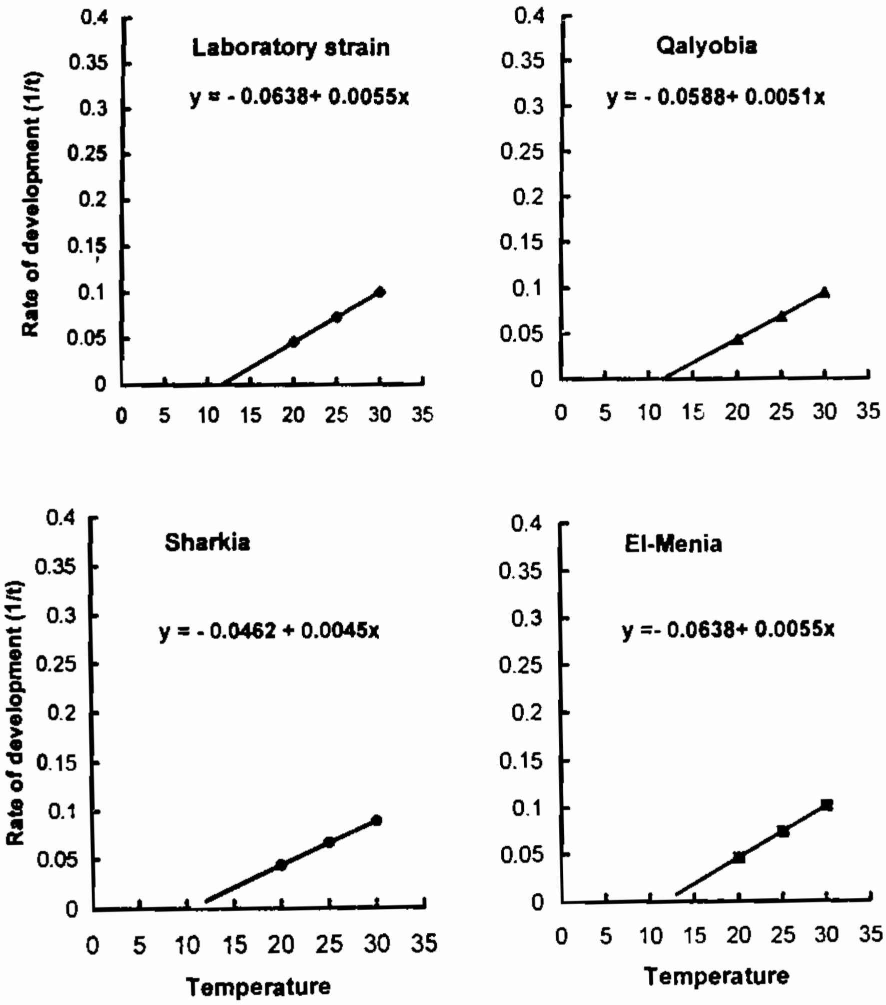

Fig. 3. The regression lines of the relation between developmental rates of *E. insulana* pupae and temperature (laboratory and field strains from different Agro-ecosystems).

5) Generation duration:

The generation duration was calculated for the laboratory strain only due to the lack of information about the pre-oviposition period of other ecosystems. Data in Table (1) show that the whole generation duration for the laboratory strain only, it ranged between 61.18, 33.80 and 27.97 days when reared on 20, 25 and 30°C, respectively.

Data in Table (2) and Fig. (4) show that the zero of development for the whole generation was estimated as 11.04°C, while the amount of thermal units needed for completing one generation were 512.82 DDs. Results are agreed with those found by Younis *et al.* (1988), Darwish *et al.* (1989) who found that zero of development for the period from egg to adult equals 11.6°C. Amin and Foda (1999); Hamid *et al.* 1999 also found the same results.

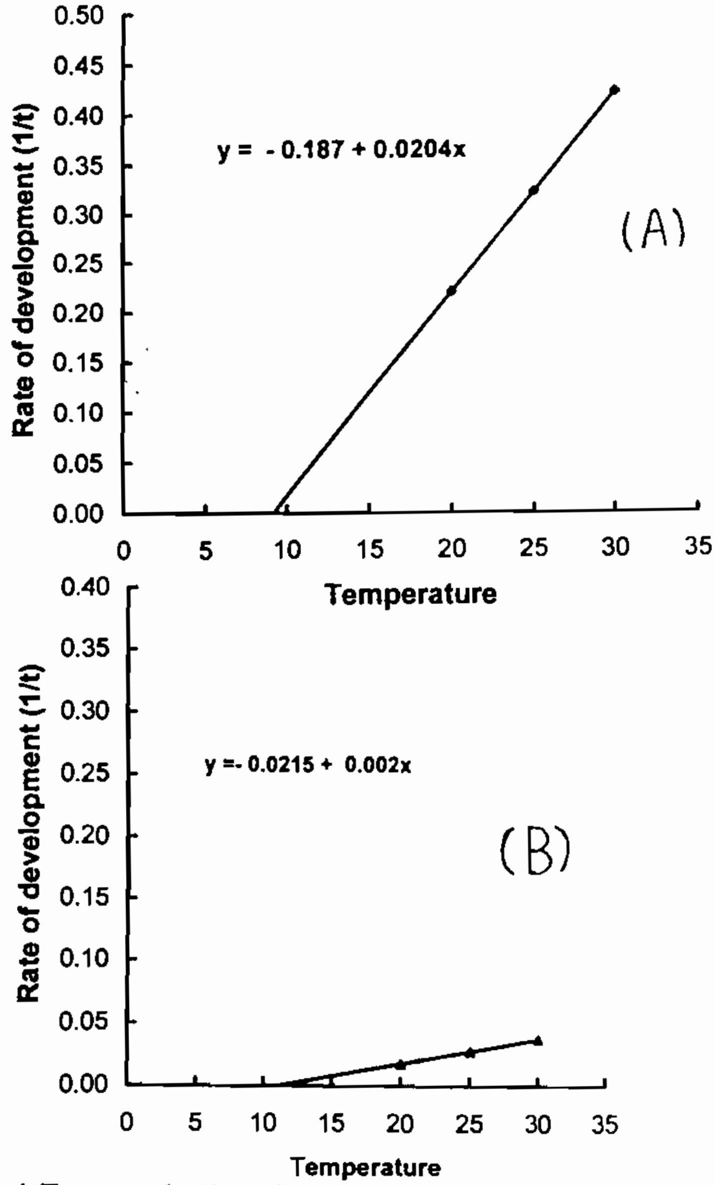

Fig. 4. The regression lines of the relation between developmental rates of *E. insulana* pre-oviposition (A), generation time (B) and temperature for laboratory strain only.

Conclusion

From the previously mentioned results it could be concluded, however that the great variability of agro-ecosystems plays an important role in the changes of the developmental threshold and thermal units of *E. insulana* immature stages. This could be useful in the prediction purposes which are used in an integrated control program of this serious pest.

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الحد الحرج للنمو والاحتياجات الحرارية اللازمة لبعض السلالات البيئيـــة لـــبعض الحشرات التي تصيب نباتات القطن:
٢ – دودة اللوز الشوكية *Earias insulana* (Boisd.)

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أجريت تجربة معملية لتحديد صفر النمو الفسيولوجي للأطوار غير الكاملة لحشرة دودة اللوز الشوكية *Earias insulana* (Boisd.) وكذلك الوحدات الحرارية التراكمية اللازمة لاتمام جيل واحد وذلك لعينات أخذت من مناطق بيئية مختلفة تمثلها محافظات القليوبية، الشرقية والمنيا بالإضافة إلي سلالة حساسة مرباة معمليا لعدة أجيال. تشير النتائج المتحصل عليها إلي أن فترة حضانة البيض قد تأثرت بشدة تبعا لدرجة الحرارة التي تمت التربية عليها. عند البيض ٢٠°م كان البيض الناتج من سلالة محافظة القليوبية أسرع تطورا بالمقارنة بالسلالات الثلاثة الأخرى. أما عند ٣٠°م فقد تراوحت مدة نمو البيض من ٢,٨–٣,٠ أيام لكل من السلالة المعملية والسلالات الحقلية. بلغ صفر النمو للبيض بين ٧,٥٥ و٧,٥٩ و١٠,٥٧°م لسلالات الشرقية، القليوبية والمنيا علي التوالي، بينما بلغت الاحتياجات الحرارية اللازمة لفقس البيض ٦٤,٦٩، ٦٠,٦١ و ٥٤,٠٥ وحدة حرارية.

كانت يرقات السلالة المعملية الأسرع تطورا بالمقارنة بالسلالات الحقلية الأخرى. عند ٢٥°م بلغت مدة الطور اليرقي ١٤,٥±١,١٥ يوم للسلالة المعملية بينما تراوحت بين ١٦–١٨ يوم للسلالات الحقلية الثلاث. لم يختلف صفر النمو بين السلالات البيئة كثيرا حيث تراوح بين ١١,٠٢ إلي ١٢,٣٩°م وقد بلغت الاحتياجات الحرارية ٢٧٧,٧٨ وحدة ليرقات المنيا ثم الشرقية (٢٤٣,٩ وحدة) ثم القليوبية (٢٣٨,٠٩ وحدة) وأخيرا السلالة المعملية (٢٢٧,٢٧ وحدة).

كانت العذارى الناتجة من السلالة المعملية كانت الأسرع نموا عن السلالات البيئية الأخرى. عند ٢٥ ، ٣٠°م كانت العذارى الناتجة من سلالات محافظات الشرقية والقليوبية هي الأسرع نموا من تلك الناتجة من محافظة المنيا. كانت قيم صفر النمو متقاربة جدا بين السلالات الأربع وقد تراوحت بين ١٠,٢٦ ، ١١,٠٦°م بينما بلغت الاحتياجات الحرارية لإتمام هذا الطور ١٨١,٨٢ وحدة لعذارى السلالة المعملية ومحافظة المنيا و١٦٨,٠٨ وحدة لمحافظة القليوبية و٢٢٢,٢٢ لمحافظة الشرقية.

نظرا لأن الإناث الناتجة من البيض المأخوذ من المحافظات المختلفة والمرباة علي بيئة صناعية لم تضع بيضا في المعمل لذا فقد تم حساب فترة ما قبل وضع البيض للسلالة المعملية فقط وقد بلغت تلك الفترة ٤,٣٣±٠,٥٥ يوم و ٢,٣٠±٠,٤٨ يوم) علي درجتي ٢٠ ، ٣٠°م علي التوالي. بلغ صفر النمو ٩,١٧°م وبلغت الوحدات الحرارية المكملة لهذا الطور ٤٩,٠٢ وحدة.

بلغت المدة الإجمالية لتكملة جيل واحد من سلالة الحشرة المرباة معمليا ٦١,١٨ يوم، ٣٣,٨٠ و٢٧,٩٧ يوم عند ٢٠ و٢٥ و٣٠°م وكان صفر النمو للجيل ١١,٠٤°م في حين بلغت الاحتياجات الحرارية لإتمام الجيل ٥١٢,٨٢ وحدة حرارية.