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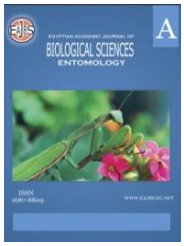

Heat Requirements for the Fall Armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) as a New Invasive Pest in Egypt

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ABSTRACT

The present study is the first attempt in Egypt which focused on determining the development rate of *Spodoptera frugiperda* at different constant temperatures, the number of degree-days (DD's) required for each stage to complete development, as well as the degree-days required for overall egg-to-adult development. The study was conducted under three constant temperatures (20, 25, and 30 °C at the Department of Zoology, Faculty of Science, South Vally University, Qena Governorate, Egypt.

The aim of this study was to determine the development rate of *S. frugiperda* at different temperatures and to calculate the number of degree-days (DD's) required for each stage to complete its development. The study showed that the mean incubation period was 6.9, 3.4, and 2.1 days at 20, 25, and 30 °C**,** respectively, and the larval duration were 38.5, 23.7, and 18.6 days at the same temperatures, respectively. On the other hand, The average pupal durations were 22.5 at 20, 9.4 at 25, and 7.7days at 30°C. For the adult stage the mean time required for maturation of the ovaries and starting to egg-laying, decreased as the temperature increased, from 4.8 days at 20°C to 2.1 days at 30°C. Meanwhile, the mean duration of generation for *S. frugiperda* was 72.7, 40.1, and 30.5 days at 20, 25, and 30°C, respectively. The lower threshold of development (t_0) and average thermal units in degree-d (dd's) were 15.79 °C and 30.0 dd's for egg stage; 10.39 °C and 360.2 dd's for the larval stage; 14.05 °C and 129.8 dd's for the pupal stage; 12.95 °C and 37.73 dd's for pre-oviposition period and 12.49°C and 527.3 dd's for a complete generation. The study of heat requirements of the fall armyworm as a new invasive pest came to Egypt from the South Africa countries is very important to determine the thermal heat units for the development and growth of this pest in order to predict the annual field generations in other supplementary studies and draw up a planning IPM strategy for this dangerous pest during the absence of any local information about it.

INTRODUCTION

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) caterpillars are major pests of cereals and forage grasses, and recorded as eating 186 plant species from 42 families Casmuz Augusto *et. al.,* (2010). It occurs in several countries such as Brazil, Argentina, and the USA (Prowell *et al*., 2004; Clark *et al., 2*007), causing economic losses in a variety of crops such as maize, soybean, cotton, and beans (Pogue, 2002; Nagoshi, 2007; Bueno *et al.,* 2010) and a number of field crops, such as rice, maize, and other grasses (Nabity *et al.,* 2011). Because of its wide host range*, S. frugiperda* is one of the harmful pests threatening annual crops in tropical regions (Andrews, 1980). The fall armyworm, *S. frugiperda* was first reported in Africa by Goergen *et. al.,* 2016) recently, the severe incidence of *S. frugiperda* was reported from African countries such as São Tomé, Nigeria, Bénin, and Togo (Sharanabasappa *et. al.*, 2018 and Igyuve 2018 in Nigeria. In Egypt, in May 2019, the Agricultural Pesticide Committee (APC) of the Ministry of Agriculture reported the first case of *S. frugiperda* presence in a maize field in a village in Kom Ombo city of Aswan Governorate, Upper Egypt. According to the Food and Agriculture Organization of the United Nations (FAO) facts, the fall armyworm landed in African via a ship or a plane in 2016, invading more than 40 African countries since then. Its large destructive impact could push 300 million people into hunger in Africa. So, the relation between temperature and development rate of fall armyworm is important for identifying the life stages and also for planning IPM strategies. Hence, this study is the first study in Egypt on the relation between temperature and development rate of FAW under constant temperatures.

Pest biology, distribution, and abundance are largely influenced by the relationship between temperature and the development rate Tobin *et. al.* (2003). Since the development of insects occurs within a specific temperature range, a change in temperature will, therefore, influence the development rate, the duration of the life-cycle, and ultimately, survival (Howe, 1967). An increase in ambient temperature near the thermal optimum of insects causes an increase in their metabolism and, therefore, also their activity Jaworski *et. al.*, (2013). The thermal optimum is the temperature at which a species develops, reproduces, and survives optimally Begon *et. al.*, (2006), and they also reported that the temperatures lower or higher than the optimum temperature lead to a decrease in the development rate. Temperature influences the duration of each instar, as well as the number of instars that larvae go through before reaching the adult stage Aguilon and Velasco (2015). A faster development rate can be advantageous to insects since it results in less time spent in vulnerable stages during which they can be attacked by predators, parasitoids, and entomopathogens Jaworski *et. al.,* (2013). The status of pest species is, therefore, affected by changes in climate and weather, Porter, 1991. It is, therefore, important that the effect of temperature on the development of target insect species under the current changing climatic conditions is known since this will contribute to risk analyses, forecasting, and management strategies in order to minimize pest infestation levels Calvo and Molina (2005). Temperatures fluctuate in natural environments and affect insect population dynamics differently from conditions where insects are only exposed to constant temperatures. Insects develop faster under fluctuating temperatures when the maximum and minimum temperatures are within their optimal range of development Hagstrum and Hagstrum (1970). However, studies of insect pest species at constant temperatures can be used to predict their seasonal and phenological development Mironidis, (2014), pest population dynamics, and timing of control strategies Shanower *et. al.,* (1993). The objectives of this study were to determine the development rate of *S. frugiperda* at different constant temperatures, the number of degree-days (DD) required for each stage to complete development, as well as the degree-days required for overall egg-to-adult development.

MATERIALS AND METHODS

Fall armyworm egg- masses were collected from maize fields at Qena Governorate, Upper Egypt. This work was carried out at the Faculty of Science, South Valley University, Qena. After egg masses hatching the larvae were transferred and reared in plastic containers (40 × 20 × 15 cm) with aerated cover (muslin) and provided with maize leaves as food. Food was replaced at three-day intervals. Larvae were reared separately from the 3rd instar onwards. This was done in small glass containers (7 cm in height × 2 cm in diameter) covered with fine muslin. Larvae were kept in an incubator at 27°C ± 1 °C, 65 ± 5% RH, and 14L: 10D photoperiod until pupation. Pupae kept in the same glass containers and incubators. Pupae were observed daily until moths emerged. After the emergence of moths, single male-female pairs were confined to oviposition glass cadge in an incubator maintained at the temperature and conditions ascribed above. The cadge and methods used are according to those described by Kruger *et al*., 2012. A plastic bottle (22 cm in height and 10 cm in diameter) was cut open at the top and filled with small crusher stones up to a height of 5 cm. One maize stem, 18 cm in length, and 2.5–3.0 cm in diameter, with the whorl intact, was placed in an upright position inside the bottle. The stem was inserted 3–4 cm into the crusher stones to keep it upright. Water was added up to a level three-quarters of the height of the stones to provide humidity and to keep the plant parts fresh. The containers were covered with a fine muslin to prevent the moths from escaping. The maize leaves and stems were replaced every day and inspected for egg batches.

For strain establishment, the eggs were maintained at the temperature and conditions ascribed above until hatching. Newly hatched larvae were transferred to clean 5-pound glass-Jars covered with muslin and secured with rubber bands. They were provided with fresh castor-oil *Ricinus communis* leaves which were renewed daily until the larvae reach the 3rd instar larvae which were reared separately from the 3rd instar onwards. This was done in small glass containers (7 cm in height × 2 cm in diameter) covered with fine muslin and contain a thin layer of fine saw-dust. Larvae were kept in an incubator at 27°C ± 1 °C, 65 ± 5% RH, and 14L: 10D photoperiod until pupation (a thin layer of fine saw-dust was spread on the bottom of every glass-Jars to help for Moisture absorbers and successful pupation). Pupae kept in the same glass containers and incubators. Pupae were observed daily until moths emerged (Pupae were kept individually in vials until moth emergence). After the emergence of moths, single male-female pairs were confined to oviposition glass cadge in an incubator maintained at the temperature and conditions ascribed above. Ten pairs of newly – emerged moths were confined into oviposition cages. Which consists of conventional mating glass bells (16cm. high and 8cm.diam.) opened at each end. Each mating-glass bell was supplied with a zigzag sheet to serve as an oviposition site and placed on its wide end on a half petri-dish. Tops of the glass bells were covered with muslin and secured with rubber bands. Cages were examined daily to replace zigzag sheet 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 % R.H. deposited egg- masses were kept in Petri-dishes, and then were available to achieve the different experiments. Insect culture for fall armyworm reared in the laboratory for at least four generations to become a sensitive strain.

Experimental Design:

This work was carried out under controlled conditions (temperature and relative humidity). Three incubators were used to provide a constant temperature of 20, 25, and 30 ± 1°C. All stages (from egg to adults) were kept under a constant temperature to determine the biological parameters of each stage.

Egg Stage:

Eggs were collected from the breeding cages at 12 hrs. intervals, in order to standardize the egg age. The collected eggs were transferred to glass vials (2.0 x 7.5 cm), subsequently, the incubation took place under the required combination of temperature and relative humidity. Four replicates of 25 eggs/each were used for testing. Observations were made daily to record the time of hatchability and the incubation period (in days) during this experiment.

Larval Stage:

To study the larval development of *S. frugiperda,* 100 newly hatched larvae were transferred, each in a separate glass tube (7.5 x 2.5 cm.) which covered with absorbent cotton and containing fresh pieces of castor oil plant leaves (25 larvae/replicate). The larvae were left in the vials (contain a thin layer of fine saw-dust) until pupation. Daily observations were made to count the pupated larvae. Larval development and duration were estimated.

Pupal Stage:

Newly formed pupae were collected on the same day of pupation and placed in the glass tube (2.0 × 7.5 cm.) (One pupae for each tube) and plugged tightly with a piece of cotton. Four replicates (each of 25 pupae) were placed at the same condition of temperature and RH% and observed daily till adult emergence. Pupal development and duration were estimated.

Adult Stage:

Ten of newly emerged moths were transferred on the same day of emergence to a glass mating-cage as mentioned before and also held on the conditions of each temperature (20, 25, and 30°C. Five replicates, each has 2 adult (1♂ +1♀), were placed at three tested temperatures. Daily observations were made to record adult longevity especially pre- ovi-potion period.

The duration of different stages (incubation period, larval duration, pupal duration, and pre-oviposition period) were calculated. Data obtained in the present studies were subjected to data analysis by standard errors.

The duration of the whole generation (egg-end of the pre-oviposition period) was also calculated. Differences in each measured parameter under different constant temperatures were examined by one-way analysis of variance (ANOVA). In order to calculate the theoretical developmental thresholds (t_0) and the accumulated thermal units (K), the regression formula was used:

$$y = a + b x$$

$$(t_0) = -a / b \text{ and } K = 1 / b$$

Where: y= developmental rate of a given stage; x= temperature in degree scentigrade; (a): constant term; (b): regression coefficient; (t_0): lower threshold of development and (K): thermal units. On the other hand, The mean number of degree-days (°D) needed for the development of the egg, larval, pupal, and pre- 76 mbryogene period stages were estimated using the equation of Jackson and Elliot (1988):

$$°D = T (C – T_{min}),$$

where T is the number of days taken to complete development at a constant temperature I and T_{min} is the minimum temperature for development. The thermal constant was used and the mean number of ◦D required for the development of each life stage at the set constant temperatures were compared.

RESULTS

Temperature is an important environmental factor that affects the rate of development survival, and the success of an insect in a given environment. From the practical aspect, the study of this parameter is particularly interesting for insects of economic importance to obtain a useful orientation for a good forecast and prediction system of the insect population. The importance of temperature occurred as indicated by **Fye and poole (1971)** who stated that the advise effects of high temperature on the pink bolloworm and other lepidopterous pests of cotton lead to the conclusion that temperature is a limiting factor in the development of such populations. Limitation of developmental requirements of the fall armyworm a trial to study the biological effects of constant temperatures on the developmental process of different stages of the *S. frugiperda* which contributes to establishing a better-integrated management program to reduce the serious damage caused by this insect pest. The aim of this study of investigation has been to establish the velocity constants (i.e. the relationship between temperature and speed of development) which gives a quantitative expression for this relationship, using thermal summation.

Stages Development:

Data in Table (1) show the incubation periods of *S. frugiperda* egg at different constant temperatures 20, 25, and 30 °C. The above-mentioned table indicated that the required time for completion of 77mbryogenesis decreased as the temperature increased for fall armyworm. The mean incubation period was 6.9, 3.4 and 2.1 days at 20, 25 and 30 °C **,** respectively. There was significant differences in the incubation periods at the different treatments of 20, 25 and 30 ºC except for between 25 and 30 ºC there is a non-significant difference. At the same three temperatures, 20, 25, and 30 °C the larval duration of *S. frugiperda* was 38.5, 23.7, and 18.6 days, respectively. Statistically, there are obvious significant differences between values of the mean durations at the tested constant temperatures for the fall armyworm larval duration. Generally, the developmental rates of *S. frugiperda* increased with the increase in temperatures from 20 to 30°C.

Concerning the effects of the three tested constant temperatures on the pupal duration of *S. frugiperda* (Table 1), it is noticed generally that the pupal periods decreased as temperature increased from 20 to 30°C. The average durations were 22.5 days at 20°C, 9.4 days at 25°C and 7.7days at 30°C. From a statistical point of view, there are significant differences between the mean of pupal duration at 20°C and the same value at all other regimes at the level of 0.05 probability, except between 25 and 30 ºC there is a non-significant difference.

Data in Table (1) show the pre-oviposition periods for the fall armyworm adult at different constant temperatures. It is appreciably clear that the mean time required for maturation of the ovaries and starting to egg-laying, decreased as the temperature increased, from 4.8 days at 20°C to 2.1 days at 30°C. From a statistical point of view, there are significant differences between the average value of the pre-oviposition period at 20°C and the value at all other regimes. Meanwhile, there are non-significant differences between the same values at 20, 25°C.

The mean duration of generation at different constant temperature regimes could be calculated using two different calculation methods, at the first method the mean duration of generation was considered as the mean times between egg-deposition and the beginning of egg deposition by emerged females (F1) (i.e. from egg deposition to the end of pre-oviposition period). In the second method, the mean generation times were determined as the total of mean durations of different developmental stages, (incubation period, larval stage pupal stage, and pre-oviposition period). Theoretically, the results obtained from these methods show approximate values for mean durations of generation at different constant temperature regimes. According to the second method which has been followed in the present study, the data in Table (1) indicates that the mean duration of generation for *S. frugiperda* was 72.7, 40.1, and 30.5 days at 20, 25, and 30°C, respectively. Statistical analysis indicated that there is a significant relationship between all the values of mean generation periods at all temperatures.

Table 1: Duration of *S. frugiperda* stages development under constant temperatures**.**

Temp. (°C)	Incubation period	Larval duration	Pupal duration	Pre-oviposition period	Generation
20	6.90 ± 0.29 a	38.5 ± 1.15 a	22.5 ± 0.88 a	4.8 ± 0.24 a	72.7 ± 1.57 a
25	3.4 ± 0.24 bd	23.7 ± 0.38 b	9.4 ± 0.28 bd	3.6 ± 0.22 a	40.1 ± 0.75 b
30	2.1 ± 0.06 cd	18.6 ± 0.72 c	7.7 ± 0.23 cd	2.1 ± 0.11 b	30.5 ± 0.82 c
L.S.D 1%	1.52	4.06	2.85	1.22	5.57

The values having the same letters vertically are non-significant for difference

Data in Table (2) Refers to the observed and expected rate of developments of egg, larvae, pupae, pre- oviposition period, and the complete generation for fall armyworm *S. frugiperda* stages. These results indicated that the rates of development were slower at 20 ºC than those at the others for *S. frugiperda* stages under constant temperatures 20 , 25 and 30 ºC. Thus, it is clear that the constant temperature in the range of 25 to 30ºC is the optimum zone for *S. frugiperda* development.

Table 2: The Observed and Expected rate of development % of *S. frugiperda* stages under constant temperatures

Temp. (°C)	Rate of development (%) for									
	Egg stage		Larval stage		Pupal stage		Female Pre-oviposition period		Generation	
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
20	14.49	13.94	2.59	2.67	4.44	5.08	20.83	18.71	1.37	1.42
25	29.41	30.50	4.22	4.06	10.63	9.35	27.77	31.99	2.49	2.37
30	47.62	47.07	5.37	5.45	12.98	13.6	47.39	45.27	3.27	3.32

Thermal Units:

Egg Stage:

Table (3) and Fig (1) indicated the lower threshold of development (t_0) and average thermal units in degree-days (dd's) required for the completion of development of *S. frugiperda* stages. It was 15.79 ºC and 30.0 dd's for the egg stage. On the other hand, data in Table (4) indicated that the three observed values for egg rate of development at the temperature range from 20 to 30 ºC for *S. frugiperda,* are a remarkably good fit to the calculated temperature – velocity line having the formula y = 3.31 x – 52.3.

Larval Stage:

Data in Table (3) and Fig (2) indicated the lower threshold of development (t_0) and average degree-days (dd's) required for the completion of development for *S. frugiperda* larval stage, it was 10.39 ºC and 360.2 dd's. Meanwhile, data in Table (4) indicated that the three observed values for the larval rate of development at the temperature range from 20 to 30 ºC for *S. frugiperda,* are a remarkably good fit to the calculated temperature – velocity line having the formula y = 0.28 x – 2.89.

Pupal Stage:

The lower threshold of development (t_0) was 14.05 ºC and the average degree-days (dd's) required for the completion of development for *S. frugiperda* pupal stage was 129.8 dd's as shown in Table (3) and Figure (3). Meanwhile, the data in Table (4) indicated that the three observed values for pupal rate of development at the temperature range from 20 to 30 ^oC for fall armyworm, are a remarkably good fit to the calculated temperature – velocity line having the formula y = 0.85 x – 12.0.

Pre- Ovipostion Period:

Table (3) and Fig (4) indicated the lower threshold of development (t_0) and average thermal units in degree-days (dd's) required for the completion of development of *S. frugiperda* stages. It was 12.95 ^oC and 37.73 dd's for the pre-opposition period and the data in Table (4) indicated that the three observed values for pre-opposition period rate of development at the temperature range from 20 to 30 ^oC for *S. frugiperda*, are remarkable good fit to the calculated temperature – velocity line having the formula y = 2.66 x – 34.4.

Table 3: Lower threshold of development (t_0) and degree-day units (dd's) of *S. frugiperda* stages under constant temperatures.

Temp. (°C)	Lower threshold (t_0) and degree-day units (dd's) for									
	Incubation period		Larval duration		Pupal duration		Pre-ovi-period		Generation	
	t_0(°C)	dd's	t_0(°C)	dd's	t_0(°C)	dd's	t_0(°C)	dd's	t_0(°C)	dd's
20	15.79	29.0	10.39	370.0	14.05	133.9	12.95	33.84	12.49	546.0
25		31.3		346.2		132.1		43.38		501.7
30		29.8		364.7		122.8		35.97		534.2
Average		**30.0**		**360.2**		**129.8**		**37.73**		**527.3**

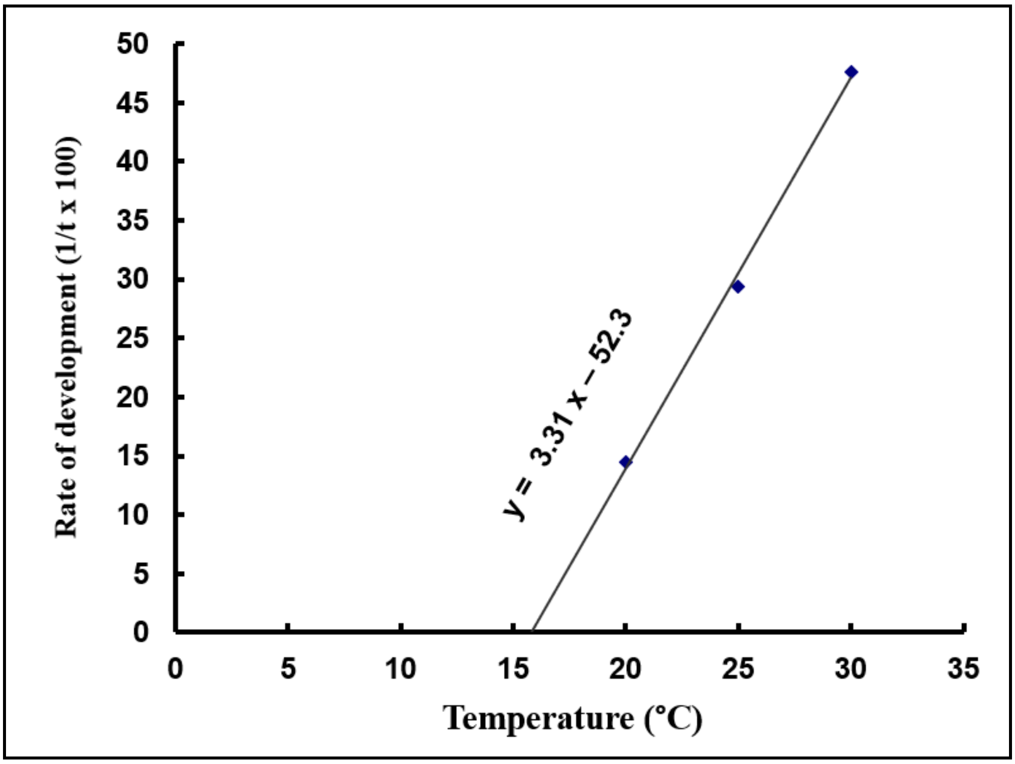

Fig.1: The regression line of the relation between the rate of development of *S. frugiperda* eggs and different constant temperature

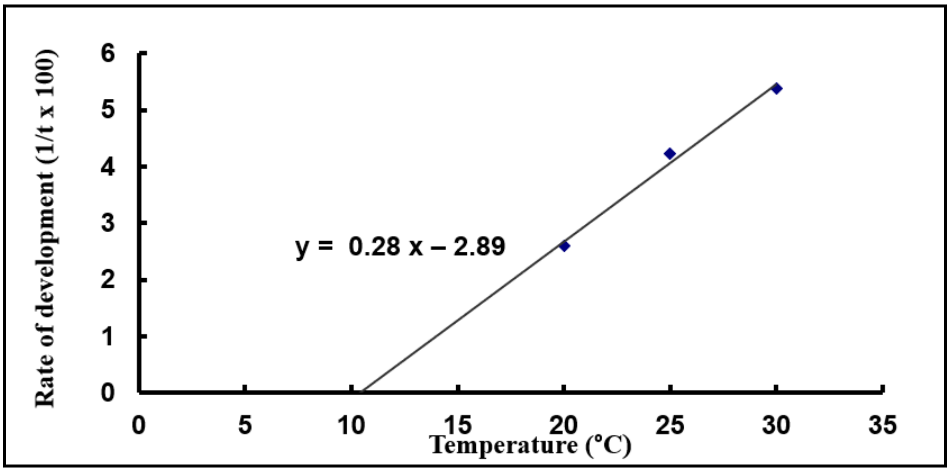

Fig.2: The regression line of the relation between the rate of development of *S. frugiperda* larvae and different constant temperature

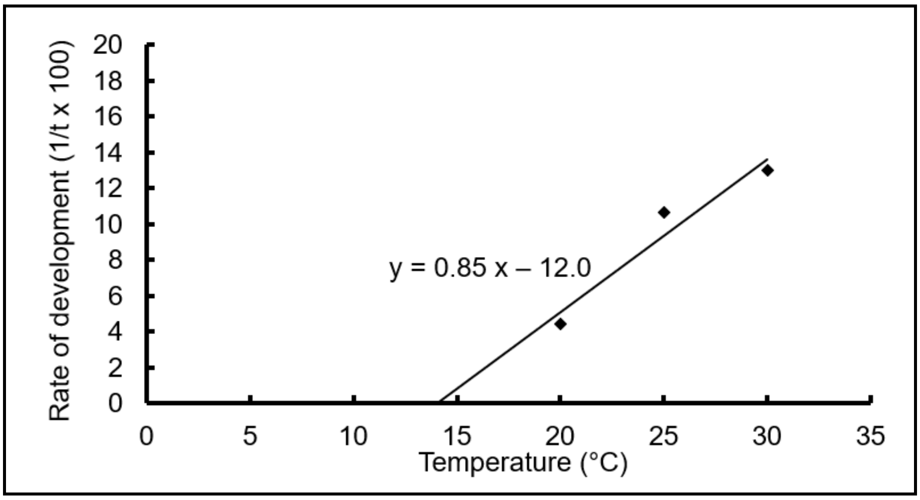

Fig.3: The regression line of the relation between the rate of development of *S. frugiperda* pupae and different constant temperature

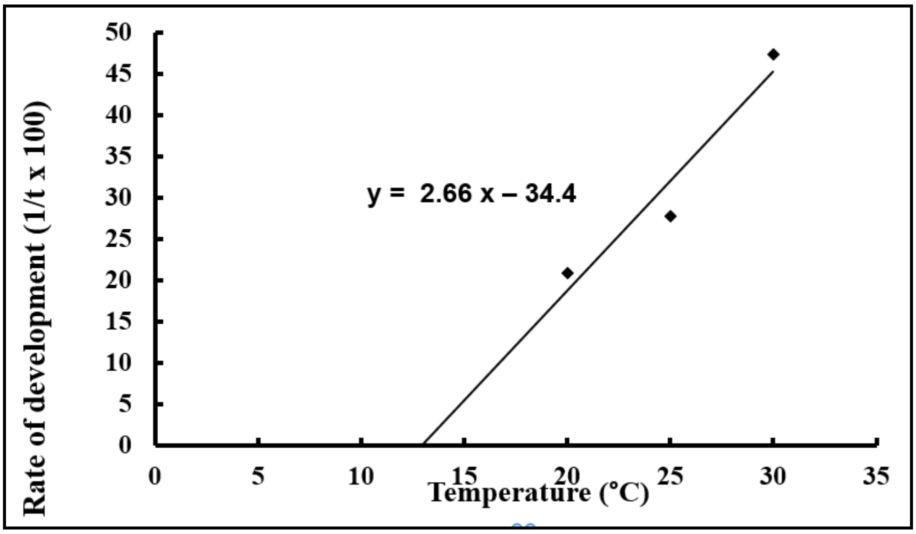

Fig.4: The regression line of pre-oviposition period of *S. frugiperda* at different constant temperature

The Complete Generation*:*

The lower threshold of development (t_0) was 12.49 ºC and the average degree-days (dd's) required for the completion of development for *S. frugiperda* complete generation was 527.3 dd's as shown in Table (4) and Fig. (5).On the other hand, the data in Table (4) indicated that the three observed values for complete generation rate of development at the temperature range from 20 to 30 ºC for fall armyworm *S. frugiperda*, are a remarkably good fit to the calculated temperature – velocity line having the formula y = 0.19 x – 2.37.

Table 4: Linear regression equations describing the relationship between the development rate (1/days); temperature and the thermal requirements of different developmental stages of *S. frugiperda.*

Development stage	Regression model	K (dd's)	t_0 (°C)	R^2 -Value
Eggs	y = 3.31 x – 52.3	30.0	15.79	0.99
Larval stage	y = 0.28 x – 2.89	360.2	10.39	0.99
Pupal stage	y = 0.85 x – 12.0	129.0	14.05	0.97
Pre- Oviposition	y = 2.66 x – 34.4	37.73	12.95	0.96
Generation	y = 0.19 x – 2.37	527.3	12.49	0.99

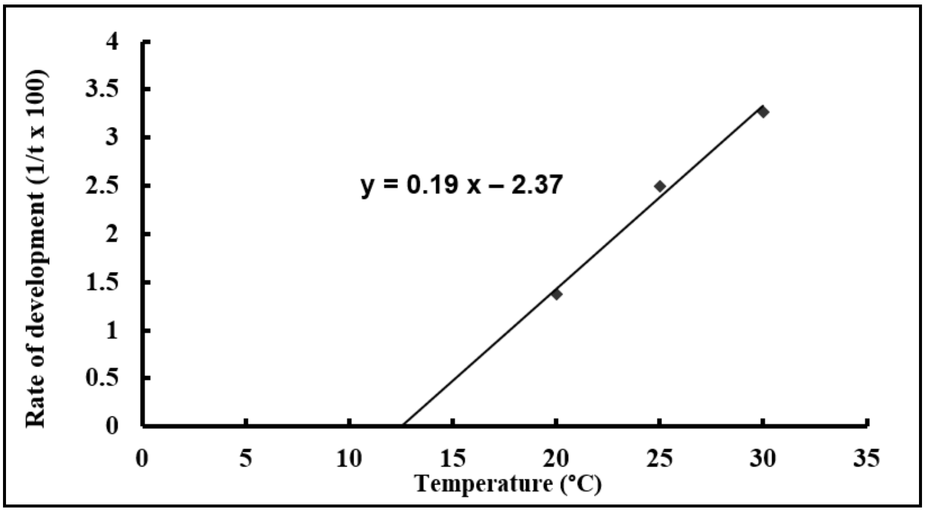

Fig.5: The regression line of the generation period of *S. frugiperda* at different constant temperature

DISCUSSION

Many authors studied the biology of fall armyworm and the relation between the different temperatures and development for fall armyworm and many insect pests, such as Howe (1967); Hagstrum and Hagstrum (1970); Tobin *et, al.,* (2003) and Jaworski and Hilszcza (2013); Igyuve1 *et. al.*, (2018) and Hannalene *et. al.*, (2020). The slight differences between authors and the present data could be attributed to the difference in the pest strains, the difference in food varieties used for larval feeding, or different temperature regimes used through laboratory studies.

The degree-day (dd's) is the most important thermal component that expresses the physiological time required to complete a specific event in an insect developmental schedule. The degree-days values of the considered parameters in Table (3) met reversible relationships with the applied thermal regimes. Such findings had been stated by several authors; Dahi, (2005) on Egyptian cotton leafworm *Spodoptera littoralis*; Dahi and Abdel-khalek (2006) on the lesser cotton leafworm *Spodoptera exigua;* Dahi *et. al*., (2009) on *Agrotis ipsilon*; Dahi, (2010): on the American bollworm *Helicoverpa armigeraI*; O'neal *et al*., (2011) on *Marmara gulosa*; Dahi *et. al.,* (2016) on *Bombyx mori* and Dahi *et. al.,* (2017) on *Palpita unionalis.* Where their obtained results clarified the importance of the relationship between growth and developmental patterns of the intended insect and its thermal requirements. Such an ecological relationship could be exploited to optimize a precise population dynamic model that could act as a vital tool in any proposed control strategy. In the same concern, the output of the current study could be a valuable guideline for the management programs that are dedicated against the fall armyworm moth through precisely detecting the time of treatment to be matched with the target stage of the pest.

Knowledge of the temperature thresholds of insects is important for predicting their potential distribution (Cammell *et. al.,* 1992 and Marco *et. al.,* 1997). The respective developmental stages have specific temperature requirements, which is important for survival in specific environments (Marco *et. al.,* 1997). The threshold temperatures determined in this study can be used to refine existing models estimating the areas suitable for crop cultivation to which *S. frugiperda* can migrate from its overwintering sites as well as areas with suitable environmental conditions for persistent occurrence.

Conclusions

Temperature thresholds determined in this study can be used as parameters to model areas that are suitable for predicting the potential distribution and permanent establishment of *S. frugiperda*. optimal range for egg, larval and egg-to-adult development of *S. frugiperda* was between 25 and 30 °C. The minimum temperature threshold for egg development was 15.79 °C, and that for larvae and pupae was 10.39 and 14.05 °C, respectively. This indicates that *S. frugiperda* populations will not develop and persist in geographical regions where temperatures decrease to below these levels during winter months.

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ARABIC SUMMARY

الاحتياجات الحرارية لدودة الحشد الخريفية كآفة غازية جديدة في مصر

حسن فرج ضاحي [1] – شريهان عبد الكريم رفاعي سالم [2] - ولاء جميل ابراهيم [1] – هند عمر محمد[3]
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تعتبر هذه الدراسة هي المحاولة الأولى في مصر التي ركزت علي دراسة معدل نمو وتطور دودة الحشد الخريفية تحت تاثير درجات الحرارة الثابتة المختلفة (20 – 25 – 30° م) وكذلك عدد الوحدات الحرارية التراكمية اللازمة لكل مرحلة من مراحل نموها من البضة الي الحشرة الكاملة. وقد أجريت هذه الدراسة تحت تأثير ثلاث درجات حرارة ثابتة (20 و25 و 30 درجة مؤية) في قسم علم الحيوان، كلية العلوم، جامعة جنوب الوادي، بمحافظة قنا بجنوب البلاد،وذلك التزاماً بالشروط التي تفرضها اللجنة الوطنية للاجراءات الاحترازية لمجابهة دودة الحشد الخريفية بوزارة الزراعة المصرية. وكان الهدف من هذه الدراسة هو تحديد معدل نمو وتطور دودة الحشد الخريفية تحت تأثير بعض درجات الحرارة الثابتة السابقة الذكر وكذلك حساب عدد الوحدات الحراية التراكمية اللازمة لكل طور من اطوار الحشرة والازمة لاستكمال تطورها. اوضحت الدراسة ان متوسط فترة حضانة البيض كانت 9.6 ، 3.4 ، 2.1 يوم علي درجة حرارة 20 ، 25 ن 30 °م ، بالترتيب. وكانت فترة حياة اليرقة 38.5 ، 23.7 ، 18.6 يوم علي نفس درجات الحرارة الثلاثة السابقة بالترتيب. وعلي الجانب الاخر، كان متوسط عمر العذراء 22.5 يوم علي درجة 20 °م ، 9.4 يوم علي درجة 25 °م ، 7.7 يوم علي درجة 30 °م. اما بالنسبة للحشرة الكاملة فكان عدد الايام اللازمة لنمو وتطور المبايض في الانثي يقل بزيادة درجة الحرارة من 4.8 يوم علي درجة 20 °م الي 2.1 يوم علي درجة 30°م، بينما كان متوسط عدد الايام اللازمة لاتمام الجيل الكامل لدودة الحشد الخريفية 72.7 ، 40.1 ، 30.5 يوم علي دراجات الحرارة 20 ، 25 ، 30°م ، بالترتيب. اوضحت الدراسة ان صفر النمو البيولوجي وعدد الوحدات الحرارية كانت: 15.79 °م مع 30.0 وحدة حرارية يومية لطور البيضة وكانت 10.39 °م مع 360.2 وحدة حرارية يومية لطور اليرقة ،وكانت 14.05°م مع 129.8 وحدة حرارية يومية لطور العذراء ، وكانت 12.95°م مع 37.73 وحدة حرارية يومية لمرحلة ماقبل وضع البيض ، واخيراً كانت 12.95 °م مع 527.3 وحدة حرارية يومية للجيل الكامل لدودة الحشد الخريفية. إن دراسة الاحتياجات الحرارية لدودة الحشد الخريفية كآفة غازية جديدة جاءت إلى مصر من دول جنوب أفريقيا مهمة جداً لتحديد الوحدات الحرارية اللازمة لنمو وتطور هذه الآفة من أجل التنبؤ بالأجيال السنوية الحقلية وذلك في دراسات مستقبلية تكميلية اخرى وذلك لوضع استراتيجية للادارة المتكاملة لهذه الآفة الخطيرة خاصةً تحت ظروف غياب كثير من المعلومات المحلية عنها.