J. of Plant Protection and Pathology, Mansoura Univ., Vol. 13 (11):267-271, 2022

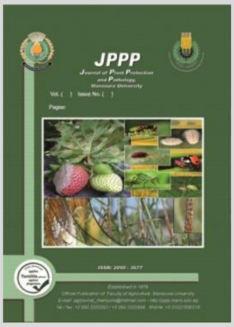
Journal of Plant Protection and Pathology

Journal homepage & Available online at: www.jppp.journals.ekb.eg

Effect of Temperature on Development and Life Table Parameters of Fall Armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

Sabra, I. M.[1]; Mervat A. A. Kandil[2]; Rania M. El-Shennawy[2*] and A. F. Ahmed[2]

[1] Dept. of Field Crop Insects Res., Plant Protection Res. Inst., Agric. Res. Center, Dokki, Giza, Egypt.
[2] Dept. of Cotton Bollworms Res., Plant Protection Res. Inst., Agric. Res. Center, Dokki, Giza, Egypt.



ABSTRACT

The effect of constant temperatures (23º, 27º, and 32±1ºC) on the development and life table of *Spodoptera frugiperda* that reared on the maize host plant was examined. The developmental times of all stages (eggs to adults) decreased linearly when temperature increased. The incubation period of the egg stage decreased significantly from 4.8 to 1.37 days when the temperature increased from 23° to 32±1°C. Temperature significantly affected on development of immature stages and subsequently the total generation time. The total immature duration lasted 47.07, 27.13, and 14.47 days at 23°, 27° and 32°C respectively. Temperature also significantly affected the life table estimates of *S. frugiperda*. The highest fecundity (717.67 eggs/♀), hatchability percent (94.29%), and net reproductive rate R_0; (85.38 females/female) of *S. frugiperda* were estimated at 27°C, whereas the highest intrinsic rate of natural increase r_m, (1.18 times/female/day) and finite rate of increase e^{rm} (1.20 times/female/day) of *S. frugiperda* were estimated at 32 °C.

Keywords: Biology, intrinsic rate of natural increase, maize, net reproductive rate.

INTRODUCTION

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith 1797) (Lepidoptera: Noctuidae) is an invasive worldwide agricultural pest that invaded Egypt in May 2019 According to the Food and Agriculture Organization of the United Nations (FAO), it caused extensive threats to field crops. It is a polyphagous pest that feeds on commercial crops, such as rice, sorghum, maize, sugarcane, wheat, cotton, and different vegetables (He *et al*, 2022; Combs *et al*, 1980 and Wu *et al*, 2021). The change in temperature affects the development rate, the duration of the life cycle, and ultimately survival (Howe, 1967). Climate change and global warming are of major concern to agriculture worldwide due to their great impact on crop production and insect pests. Temperature is considerable a biotic important environmental factor affecting the seasonal fluctuation and population dynamics of all pests on some host plants in the field (Hoffmann *et al.*, 2003 and Tran *et al.*, 2007). Temperature determines the probability of mortality and hence, population declines, especially at extremes (Chown and Terblanche, 2007) besides it increases the risk of invasive insect species, (Skendžić *et al.* 2021). Therefore, it is important to study the effect of temperature on the development of target insect species under the recently changing climatic conditions, which will contribute to risk analyses, predictions, and management strategies to reduce pest invasion levels (Calvo, and Molina, 2005 and Kandil, 2013). Life table studies are considered a prediction style for the population development of insects.

The main parameters that have to be calculated by the life table program (prediction parameters) are female progeny/ female (mx), rate of survival (lx), developmental time, sex ratio, the fraction of eggs reaching maturity, net reproductive rate (R_0), average generation calendar period (T), intrinsic rate of natural increase (r_m), and finite rate of increase (e^{rm}). Knowledge of these parameters would be useful in control programs of this insect pest.

Little information is available on the effects of different temperatures on the whole life cycle and population of *S. frugiperda* (Díaz-Álvarez *et al*, 2021 and Combs *et al*, 1980). Hence, it was essential to evaluate the consequence effects of changes in temperatures on the population growth and performance of these important insect pests. Therefore, this study planned to examine the effect of temperatures (23°, 27°, and 32±1 °C) on the development and life table parameters of *S. frugiperda*.

MATERIALS AND METHODS

Samples of different stages (egg patches, larvae, and pupae) of *S. frugiperda* were collected at various times from maize plants in El-Fayoum governorate, Egypt. Samples of similar stages were categorized into instars. All collected samples were transferred to Bollworms Research Department, Plant Protection Research Institute.

Laboratory rearing technique of *S. frugiperda*:

Collected stages of *S. frugiperda* were reared at room temperature (22°C - 35°C) with a relative humidity of 70 ± 5 % RH for one generation for homogeneity. Reared larvae were allowed to be fed on the maize host plant and inspected daily (with food replacement two days intervals) till pupation. Pupae were placed in a glass jar with tissue paper in its bottom and covered with muslin clothes till adult emergence. Under the same constant conditions, every male-female pair of emerged adults was placed individually in rearing cages covered from both sides with a muslin cloth. Another piece of muslin cloth was hung inside the cage for

[*] Corresponding author.
E-mail address: Raniashennawy2017@yahoo.com
DOI:10.21608/jppp.2022.169253.1107

oviposition. Moths were allowed to be fed on 10% sucrose solution through suspended cotton balls inside the cage. Deposited eggs were collected daily for subsequent experiments.

Experimental design:

Three incubators were used to provide constant temperatures (23, 27, and 32 °C ±1), with a relative humidity of 70 ± 5% RH. Egg patches 0-1 day old were collected from the breeding cages and transferred to glass vials (2.0 x 7.5 cm). These vials were kept at the tested temperatures. Three replicates (50 eggs/rep.) were prepared for each temperature degree. Eggs were checked daily to record the incubation period and the hatchability percentages. At each temperature degree, neonates of *S. frugiperda* were isolated in Petri dishes (9 cm in diameter) with maize leaves as a food source. Developmental rates of larval and pupal stages were inspected till adult emergence. Newly emerged adults were paired and confined to an oviposition cage. Five replicates of single male-female pairs were prepared for each tested temperature. Cages were observed daily and the number of eggs was recorded.

Biological aspects:

Biological aspects of *S. frugiperda*; developmental time for different stages, mortality and malformation percentages, and life cycle were estimated. In addition, female (pre-pviposition, oviposition, and post-oviposition periods) and male longevities, fecundity (the total number of eggs laid/female) and female fertility were also estimated.

Egg hatchability was calculated according to Zidan and Abdel-Megeed, (1987), and the mortality of larval and pupal stages was corrected according to Abbott's formula (1925).

Life table parameters:

Data of the life table were analyzed by using the life 48 basic computer program of Abou - Setta *et al*. (1986).

Statistical analysis:

All biological aspects of *S. frugiperda* were analyzed, using Costas Statistical Program Software (1990) and means separated using Duncan's Multiple Range Test at the 5 % probability level.

RESULTS AND DISCUSSION

A- Effect of temperature on some biological aspects of *Spodoptera frugiperda.*

The fall armyworm *S. frugiperda* was reared at three temperature degrees (23, 27, and 32±1ºC) to study the effects on some biological aspects. Generally, temperature significantly influenced the developmental cycle of the insect from egg to adult where the developmental time was significantly decreased as the temperature increased.

Eggs incubation period:

Data in Table (1) indicated that the incubation period of eggs decreased significantly from 4.8 days at 23±1°C to 2.5 days at 27±1°C and 1.37 days at 32±1°C.

Larval and pupal duration:

The development times for all larval instars, pre-pupal, and pupal stages significantly decreased as the temperature increased; the larval duration was 28.27 days at 23±1°C while it was 17.33 days at 27±1°C and 9.2 days at 32±1 °C. A similar trend was also recorded for the pre-pupal and pupal stages. Subsequently, temperature significantly affected the duration of total immature stages (Table 1).

Mortality and malformation percentages:

Temperature affected mortality and malformation of both larvae and pupae of *S. frugiperda*. The lowest mortality rates of larvae (4%) and pupae (5%) were reported at 27±1°C. These percentages increased significantly to 15.33 and 20.67 % for larvae and 14.33 and 11.33 % for pupae at 23±1 and 32±1°C respectively, (Table 1 & Fig. 1).

Table 1. Impact of three temperatures on some biological parameters of *Spodoptera frugiperda.*

Parameters	Rearing temperatures(°C)			LSD 0.05
	(23±1°C)	(27±1°C)	(32±1°C)	
Incubation Period ±SE (days)	4.8±0.28^{a}	2.5±0.06^{b}	1.37±0.24^{c}	0.76
Larval Period ±SE (days)	28.27±0.67^{a}	17.33±1.2^{b}	9.2±0.41^{c}	2.92
Larval Mortality &Malformation (%)	15.33^{a}	4.0^{b}	20.67^{a}	5.96
Pre-Pupal Period(days)	3.13±0.36^{a}	1.7±0.2^{b}	0.93±0.06^{b}	0.78
Pupal Period ±SE (days)	15.67±1.2^{a}	8.1±0.01^{b}	4.67±0.60^{c}	2.75
Pupal Mortality &Malformation (%)	14.33^{a}	5.0^{a}	11.33^{a}	9.35
Total Immature Duration ±SE (days)	47.07±1.7^{a}	27.13±1.3^{b}	14.47±0.5^{c}	4.46

Note: Values within one row followed by different letters are significantly different at the 0.05 level

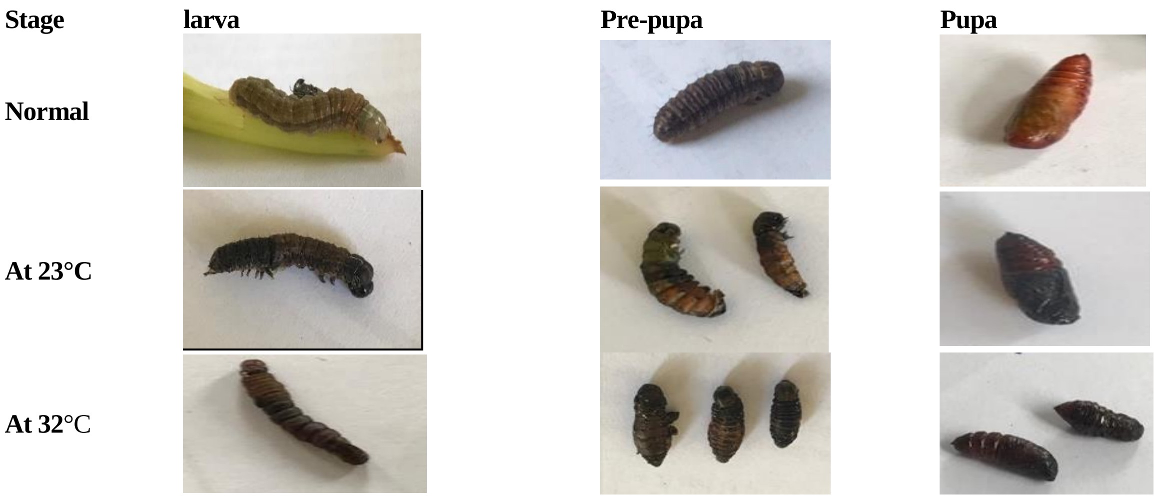


Fig. 1. Some morphological distortions of *S. frugiperda* immature stages at low and high temperatures

Adult duration:

Oviposition periods of *S. frugiperda* females at the three consistent temperatures are estimated and presented in Table (2). The pre-oviposition period increased significantly by decreasing temperature, as it was 4.97 days at 23±1°C, whereas it decreased significantly to 3.3 days as temperature increased from 23 to 27±1°C, and finally dramatically declined 0.93 days as temperature increased from 27 to 32±1 °C. However, the oviposition period was 5.97 days at a 23±1°C and reduced insignificantly to 4.63 days at 27±1°C and significantly to 2.67 days at 32±1 °C. Consequently, different temperatures significantly affected adult longevities that were 14.27, 10.87, and 6 days for females and 10.9, 8.17, and 4.23 days for males at previously mentioned temperatures, respectively. Also, the life cycle of *S. frugiperda* decreases significantly to 37.82, 94.37, and 20.03 days as the temperature increase, (Table 2).

Table 2. Effect of temperatures on longevity and reproductive performance of *Spodoptera frugiperda*.

Parameters		Rearing temperatures(°C) 23±1°C	27±1°C	32±1°C	LSD 0.05
Duration ±SE (days)	Pre-Oviposition	4.97±0.180^{a}	3.3±0.21^{b}	0.93±0.03^{c}	0.58
	Oviposition	5.97±0.30^{a}	4.63±0.20^{a}	2.67±0.01^{b}	1.85
	♀. Longevity	14.27±0.67^{a}	10.87±0.29^{b}	6.0±0.03^{c}	2.25
	♂. Longevity	10.9±0.70^{a}	8.17±0.35^{b}	4.23±0.40^{c}	2.06
	Life Cycle	51.87±1.80^{a}	29.63±1.4^{b}	15.83±0.73^{c}	4.91
Total Egg/ ♀ (fecundity)		334±76.50^{b}	717.67±63.10^{a}	444.67±36.79^{b}	213.51
Fertility	No. Hatched Egg	126.33±36.70^{b}	676.67±41.79^{a}	88.67±39.60^{b}	154.3
	Hatchability (%)	37.82^{b}	94.37^{a}	20.03^{b}	39.4

Note: Values within the same letters within a raw are not significantly different at the 0.05 level.

Reproductive performance:

Results in Table (2) show that female *S. frugiperda* produced the highest mean number of deposited eggs (717.67 eggs/female) with the highest hatchability percent (94.37 %) at 27±1°C. These values were significantly reduced to 334 eggs / female and 37.82% and 444.67 eggs / female and 20.03% at 23 and 32±1°C, respectively.

B- Life table parameters:

Temperature drastically affected the life table parameters of *S. frugiperda* (Fig. 2, and Table 3).

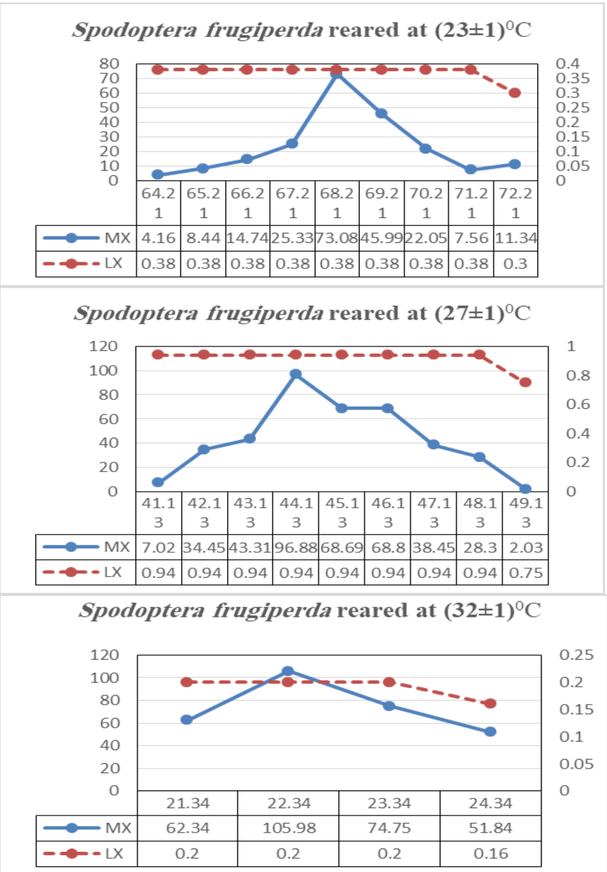


Fig. 2. Effect of different temperatures on female progeny/ female (Mx) and survival rate (Lx) of *S. frugiperda* moths.

Estimates of the life table of *S. frugiperda* given in Table (3) indicated the variation in r_m as well as e^{rm} values of *S. frugiperda* by different temperatures. The highest values of r_m and e^{rm} were estimated at 32±1°C. The generation time (T) dramatically decreased as temperature increased. Although the highest temperature accelerated the generation time (T), it decreased the net reproductive rate (R_o). The highest value of R_0 was estimated at 27±1°C (Table 3). The sex ratio value was the highest (0.54 females' total population) at 27±1°C, compared to other temperatures (Table 3).

Table 3. Effect of temperature on life table parameters of *S. frugiperda*.

Temperature ±1°C	(T) days	(R_0)	Rate of population increase (r_m)	(e^{rm})	Sex ratio
23	68.37	79.58	0.17	1.07	0.63
27	44.63	85.38	0.14	1.14	0.54
32	22.60	56.74	0.18	1.20	0.64

(T) = The generation time.
(R_0) =The net reproductive rate.
(r_m) = The intrinsic rate of natural increase.
(e^{rm}) = The finite rate of increase.

Presented data in figure (2) illustrated that the female progeny/ female (Mx) parameter of *S. frugiperda* ranged between 2.03 -96.88 at 27±1°C as compared with 4.16 -73 at 23±1°C while increased at 32±1°C to 51.84 -105.98. The rate of survival (Lx) of *S. frugiperda* was the highest at 27±1°C ranging between (0.75 – 0.94), compared to 0. 30 - 0.38 at 23±1°C and 0.16 – 0.20 at 32±1°C. Therefore, it can be concluded that at 27±1°C is the most suitable for rearing *S. frugiperda* due to the higher increases in survival and reproduction rates compared to the two other tested temperatures. Moreover, the sex ratio value was 0.54 females/ total at 27°C while increased partially to 0.63 and 0.64 females/ total when reared at 23 and 32°C respectively, (Table 3).

Discussion

As temperatures increased the developmental rate increased, resulting in more generations during the crop-growing season (Díaz-Álvarez *et al*, 2o21; Barfield *et al*, 1987; Plessis *et al* 2020 and Garcia *et al*, 2017).

Results indicated that temperature significantly influenced the survival, development, reproduction, and population growth of *S. frugiperda*. The lower mortality rate of *S. frugiperda* larvae and pupae in addition to higher reproductive performance was recorded at 27±1°C, which decreased with changes in temperatures. The present study indicated that increasing temperatures significantly shortened the developmental time of *S. frugiperda* eggs, larvae, pre-pupae, pupae, and adults, accordingly, accelerated generations. Likewise, Barfield *et al*. (1987); Plessis *et al*. (2020), and Huang *et al*., (2021) stated that the developmental time of the immature stages of *S. frugiperda* is significantly influenced by temperature since it is significantly reduced at higher temperatures. Also, Plessis *et al*. (2020) found that the longevity of *S. frugiperda* significantly declined at 30 ºC, but did not at21 to 25◦C. Dahi *et al*. (2016) reported that the optimal range for egg, larval and egg-to-adult development of *S. frugiperda* was between 25 and 30 °C. However, the differences in *S. frugiperda* development based on temperature might help predict *S. frugiperda* occurrence in both ordinary and extreme climatic conditions (Plessis *et al*., 2020). In this study, temperature significantly influenced the reproduction parameters of *S. frugiperda*. The reduction in fecundity, fertility, and reproductive parameters probably is due to inhibition in the metabolism process (Kandil, 2013). Life table studies are essential means of understanding population dynamics (Behnaz *et al*., 2015). Various studies are conducted to understand the pest dynamics at different temperatures. Results revealed that values of (r_m) and (e^{rm}) of *S. frugiperda* increased by increasing temperature. *S. frugiperda* exhibited a higher R_0 at 27 °C than at 23°C. Similarly, Chen YC *et. al*., (2022), found that increased temperature led to significant effects on the population parameters ($R_{0,}$ r_m and e^{rm}) of *S. frugiperda*. They also reported that the low temperatures appeared to eliminate temperature-mediated synergism in *S. frugiperda* performance. Therefore, climate fluctuation is animportant cause of increasing habitat distribution and invasion hazards of invasive species (Winder *et al*., 2011)

CONCLUSION

The relationship between the developmental responses of insects and the temperature is necessary to understand the ecology of insects' life history. Results indicated that temperature significantly influenced the survival, development, reproduction, and population growth of *S. frugiperda*. There was an inverse correlation between temperature and the time required for the development of *S. frugiperda* stages. Temperature of 27°C seems to be more suitable condition for *S. frugiperda* since the insect exhibited a low mortality rate for larvae and pupae, and high net reproductive rate performances. However, both (r_m) and (e^{rm}) rates for *S. frugiperda* were the highest at 32 ºC.

REFERENCES

Abbott WW (1925). A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-26.

Abou-Setta MM Sorrel RW Childers CC (1986). Life 48: A basic computer program to calculate life table parameters for an insect or mite species. Florida Entomol. 69 (4): 690-697.

Adams KM, Kate Pedro DK, Dunca LF (2012). Perception and use of Information and Communication Technologies (ICTs). J. Libr. Sci. Res. 9: 165-174.

Barfield CS, Ashley TR (1987). Effects of corn phenology and temperature on the life cycle of the fall armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae). Fla. Entomol. 70: 110–116.

Behnaz HT, Sahragard A, Karimi-Malati A (2015). A laboratory and field condition comparison of life table parameters of *Aphis gossypii* Glover (Hemiptera: Aphididae). J. of Plant Protection Res. 55:1-7.

Calvo D, Molina JM (2005). Developmental rates of the lappet moth Streblote panda Hübner (1820) (Lepidoptera: Lasiocampidae) at constant temperatures. Span. J. Agric. Res. 3: 1–8.

Chen YC, Chen DF, MF Yang MF, Liu JF (2022). The Effect of Temperatures and Hosts on the Life Cycle of Spodoptera frugiperda (Lepidoptera: Noctuidae) Insects. 13: 211.

Chown SL, Terblanche JS (2007). Physiological diversity in insects: ecological and evolutionary contexts. Advances in Insect Physiology. 33: 50-152.

Combs RL, Valerio JR (1980). Biology of the fall armyworm on four varieties of bermudagrass when held at constant temperatures. Environ. Entomol. 9:393-396.

Dahi H F, Sherehan ARS, Walaa EG, Hend OM (2020). Heat Requirements for the Fall Armyworm Spodoptera frugiperda (J. E. Smith) (Lepidoptera: Noctuidae) as a New Invasive Pest in Egypt, Egypt. Acad. J. Biolog. Sci. (A. Entomology). 13: 73-85.

Díaz-Álvarez EA, Martínez-Zavaleta JP, López-Santiz EE, Barrera EDA, Larsen J, Del-Val E (2021). Climate change can trigger fall armyworm outbreaks: A developmental response experiment with two Mexican maize landraces. Int. J. Pest Manag. 1-9. [CrossRef]

FAO. Report of first detection of *Spodoptera frugiperda* - Fall Armyworm (FAW) in Egypt. IPPC (International Plant Protection Convention) Official Pest Report, No. EGY- 01/1. FAO: Rome, Italy; 2019.

Garcia AG, Godoy WAC (2017). Thomas, J.M.G.; Nagoshi, R.N.; Meagher, R.L. Delimiting strategic zones for the development of fall armyworm (Lepidoptera: Noctuidae) on corn in the state of Florida. J. Econ. Entomol. 111: 120-126.

He LM, Wang TL, Chen YC, Ge SS, Wyckhuys KAG, Wu KM (2021). Larval diet affects development and reproduction of East Asian strain of the fall armyworm, Spodoptera frugiperda. J. Integr. Agric. 20: 736–744.

Hoffmann AA Sørensen JG, Loeschcke V (2003). Adaptation of Drosophila to temperature extremes: bringing to gather quantitative and molecular-approaches. Journal of Thermal Biology. 28: 175-216.

Howe RW (1967). Temperature effects on embryonic development in insects. Annu. Rev. Entomol. 12:15-42.

Huang LL, Xue FS, Chen C, Guo X, Tang JJ, Zhong L, He HM (2021). Effects of temperature on life-history traits of the newly invasive fall armyworm, Spodoptera frugiperda in Southeast China. Ecol. Evol. 11:5255-5264.

Kandil MA (2013). Relationship between temperature and some biological aspects and biochemical of *Earias insulana* (Boisd.) (Lepidoptera: Noctuidae). Egypt acad. J. Biology since. 6: 11-20.

Plessis, H.D.; Schlemmer, M.L.; Berg, J.V.D. (2020). The effect of temperature on the development of Spodoptera frugiperda (Lepidoptera: Noctuidae). Insects 2020, 11, 228.

Skendžić S Zovko M, Živković IP, Lešić V, Lemić D (2021). The impact of climate change on agricultural insect pests. Insects. 12, 440

Tran DH, Ridland PM, Takagi M (2007). Effect of temperature on the mature development of the some leek leafminer *Liriomyza chineusis* (Diptera: Agromyzidae). Environ. Entomol. 36: 40-45.

Winder M, Jassby AD, Mac-Nally R (2011). Synergies between climate anomalies and hydrological modifications facilitate estuarine biotic invasions. Ecol. Lett. 14:749–757.

Wu LH. Zhou C, Long GY, Yang XB, Wei ZY, Liao YJ, Yang H, Hu CX (2021). Fitness of fall armyworm, Spodoptera frugiperda to three solanaceous vegetables. J. Integr. Agric. 20: 755-763.

Zidan H Abdel-Megeed MI (1987). New Trends in pesticides and pest control - Part II Al-Dar Al-Arabia for publishing and distribution, Cairo, Egypt.

تأثير درجة الحرارة على تطور وجدول حياة دودة الحشد الخريفية *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

ابراهيم مخيمر صبرا[1] ، ميرفت عبد السميع قنديل[2] ، رانيا محمود الشناوي[2] و أشرف فايز أحمد[2]

[1]قسم بحوث المحاصيل الحقلية – معهد بحوث وقاية النباتات - مركز البحوث الزراعية
[2]قسم بحوث ديدان اللوز - معهد بحوث وقاية النباتات - مركز البحوث الزراعية

الملخص

أثبتت الدراسة أن تأثير درجات الحرارة الثابتة (23 ، 27 ، 32 ± 1 درجة مئوية) على التطور ودورة الحياة لـ *Spodoptera frugiperda* والتي تمت تربيتها على نبات الذرة كعائل لها. و قد انخفضت فترات النمو بزيادة درجة الحرارة لجميع المراحل العمرية من البيض حتى الحشرات الكامة. انخفضت فترة حضانة البيض بشكل ملحوظ من 4,8 إلى 1,37 يوم وذلك بارتفاع درجة الحرارة من 23 درجة إلى 32 ± 1 درجة مئوية . وقد أثرت درجة الحرارة بشكل كبيرعلى تطور الأعمار غير الناضجة وبالتالي على إجمالى مدة الجيل لتسجل 47,07 و 27,13 و 14,47 يومًا للأطوار الغير كاملة عند درجة حرارة 23 و 27 و 32 درجة مئوية على التوالي . كما أثرت درجة الحرارة أيضًا بشكل كبير على دورة الحياة لحشرة *S. frugiperda* المختبرة, وكانت أعلى نسبة خصوبة (67, 717 بيضة/للأنثى البالغة) ، ونسبة فقس (94,29٪) ، بالاضافة الى اعلى معدل للتكاثر R_0 (85,38 أناث/أنثى) للحشرة المختبرة *S. frugiperda* عند 27 درجة مئوية ، في حين كان أعلى معدل حقيقى للزيادة الطبيعية r_m (0,18 مرات/أنثى/يوم) وكان معدل زيادة e_{rm} محدود حيث سجل (1,20 مرة/ أنثى/يوم) لـ *S. frugiperda* عند درجة حرارة 32 درجة مئوية.