# Influence of temperature on some biological attributes of Fall Army Worm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera; Noctuidae), on Maize

**Morad, L. Ali, Mandour, N. Said, Osman, M. Abdelnaeim, Mohamed, K. Mahmoud and Abd El-Hady, M. Ali**

Plant Protection Department, Faculty of Agriculture, Suez Canal University 41522, Ismailia, Egypt

*Received :4/7/2024*

**Abstract:** The Fall Army Worm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), has been detected as a new exotic invasive pest in Egypt at the end of 2019 and it has become the most economically destructive pest of maize crop in Egypt. The main objective of current work is to study the effect of four constant temperatures (20, 25, 30, 35±1°C) on the biological attributes of FAW. The overall total developmental period of FAW was negatively correlated to the increase of temperature being longest 27.37 days at 20 °C and shortest of 15.53 days on 35 °C. Lifetime fecundity of FAW also significantly affected by temperature, the mean daily fecundity of FAW was 23.42, 66.17, 134.33 and 175.67 eggs/female at 20, 35, 30 and 25 °C, respectively. The respective total lifetime fecundity was 237.08, 1547.08, 911 and 223.5 eggs/female. The longevity of either males or females decreased as temperature increased. Generation survival rates was highest (83.33%) at 25 °C and lowest (70%) at 30 and 35 °C. At 20 °C, the generation survival rates were 60.00%. Therefore, the optimum temperature for the population growth of *S. frugiperda* ranged between 25 to 30 °C.

***Keywords:*** *Spodoptera frugiperda*, biological development, constant temperatures

## INTRODUCTION

Ambient temperature is one of the most important environmental factors influencing the biology, physiology and behavior of insects (Ratte, 1985; Briere *et al.,* 1999; Honek, 1999). Moreover, since insects are strongly temperature-dependent, it can be expected to significantly affect the seasonal population dynamics by affecting several biological attributes such as adult life span, survival, fecundity, fertility and rate of population growth (Huffaker *et al.,* 1999; Infante, 2000; Huey and Berrigan, 2001). Thus, the response to local environmental conditions is a key component for the adaptation and persistence of insect pests, particularly invasive alien species. *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is currently considered to pose a major threat to agriculture and food security in Africa, as it has caused an estimated loss about 73% of maize yield, a cereal on which 208 million people in the region depend, equivalent to an economic impact of USD 9.8 billion (FAO Statistics, 2022). Maize is the preferred host for *S. frugiperda* in the countries where it has been recorded, and according to other estimates, annual maize production loss might be 21-53% in the absence of effective control methods (Huang *et al.,* 2020). Due to its characteristic of the insect, high reproductive potential, short life cycle, great mobility and widespread distribution on various crop species, it has a serious impact not only on the economic crops but also on the food security. Controlling this pest is considered an extremely challenging task (Assefa and Ayalew, 2019; Matova *et al.,* 2020). Therefore, the main objective of the current study is to investigate the effects of different temperature regimes on the biological attributes of FAW under laboratory conditions.

## MATERIALS AND METHODS

**Rearing of FAW:** Laboratory culture of FAW was originated from the samples of infested maize plants collected from fields in Sarabeum Village, Ismailia Governorate, in November, 2020. The infested leaves or stems, containing different immature stages, were transferred to the insect rearing laboratory of Biological Control Center (BCC), Plant Protection Department, Suez Canal University. Samples were kept in rearing cages (20 cm in width × 40 cm in length ×15 cm in height), with well-ventilated covers and maintained under rearing conditions (25±2°C; 60±10% RH and 16 L: 8 D). Cages were supplied with fresh maize plants, which were replaced at regular intervals, every two days for the completion of FAW larval development. Larvae were reared separately from the $3^{rd}$ instar onwards. This was done in small plastic tubes (70 mm in height × 20 mm in diameter) with fine muslin cloth, provided with pieces of fresh maize plants for the completion of the development of the immature stages. Newly formed pupae were collected twice daily and kept in glass tubes (0.2 × 7.5 cm) and closed tightly with a piece of cotton until emergence. Adults were collected and confined in an ovipositional cage (40 cm in

*Corresponding author e-mail: lailamorad_staf@agr.suez.edu.eg

width×60 cm in length×80 cm in height), three of its sides covered by organza and one side covered with glass. Within each cage, a piece of cotton moistened with 10% honey solution was inserted for moth feeding and fresh maize plants were provided for egg deposition. The maize plants (15-day old; 30 cm in height) harboring eggs of FAW were transferred daily to immature stages rearing cages and replaced by fresh Maize plants and so on until the death of all FAW adults. Upon hatching, maize leaves bearing FAW eggs were placed in immature rearing cages, similar to those described before, and surrounded by other intact maize plants. Under the above-mentioned conditions, hatching occurred 2-3 days after oviposition. After 21-22 days, the full-grown larvae of FAW were ready for pupation, which took place inside maize stem or on sawdust, on the surface of plant leaves.

**Effects on immature development:** Four temperature regimes (20, 25, 30 and 35±1°C) were studied under laboratory conditions of 60±10% R.H. and 16:8 L/D photoperiod. Thirty replicates, each containing a single egg of FAW, were selected from the mother colony (newly deposited, <6 hours) and separated individually. Each egg was placed in a clean Petri dish (15 cm) and closed by a rubber band as a replicate. Upon hatching, newly hatched larvae were introduced to fresh pieces of small maize leaves as larval food and leaves were replaced daily until pupation. The development of FAW was monitored and data were recorded every 12 h in terms of incubation period, larval periods, pupal period and immature survival.

**Effects on adult stage:** The effects of different tested temperatures on the adult stage were studied under the same laboratory conditions as previously mentioned in immature stages. Twelve glass jars (12×22 cm) each contains a couple of FAW adults were prepared as replicate. FAW mated adults were provided by small droplets of honey solution on the inner wall as food. Small maize plants were provided for each couple as ovipositional substrate. Females of FAW laid their eggs mostly on the provided maize plant. In case of laying eggs in the inner wall of the glass jars, these eggs were counted and removed smoothly by the aid of fine camel hairbrush. Adults were checked daily and the numbers of deposited eggs, alive and dead adults were recorded until the death of all tested females or males. In each temperature regime, 12 pairs of FAW adults were tested.

**Statistical analyses:** All data were statistically analyzed using one-way ANOVA (SPSS, 2013). In case of significant F-values, means were separated by Student-Newman-Keuls Test at a 0.05 level of significance.

## RESULTS

**Effects on immature development:** Obtained results indicated that temperature had a profound and significant impact on the development of all immature stages of FAW (Fig 1). The incubation period of FAW eggs was significantly affected by temperature. As temperature increased, there was a significant reduction in incubation period (F= 38.04; P= 0.000). The shortest incubation period recorded was 1.52 days at 30°C, the longest one (5.38 days) was observed at 20°C. In other tested temperatures, the incubation period was intermediate; being 2.17 and 1.67 days at 25 and 35°C, respectively. As for the duration of total larval development, there was also a significant impact for temperature on this stage (F= 6.11; P= 0.000). The FAW had shortest total larval duration of 11.60 days at 35°C, followed by 13.28 days at 30°C. The longest larval duration was 19.55 days recorded at the lowest tested temperature of 20°C. While the total larval duration at 25°C was in-between being 14.53 days (Fig. 1). The data obtained on pupal stage indicated that temperature also had a significant effect and negative correlation with pupal duration (F= 8.388; P=0.000). The pupal periods lasted about 3.63, 3.95, 6.13 and 8.15 days at 20, 25, 30 and 35°C, respectively. As for the total developmental period (TDP) of FAW, it was found to be negatively correlated to the increase of temperatures, as the longest period was 27.37 days at the lowest tested temperature (20°C) and the shortest one was 15.53 days on the highest tested temperature. Statistical analysis indicated that there were significant differences between the tested temperatures in terms of total developmental periods of FAW (F= 4.040; P= 0.009).

### Effects on survival

Figure (2) shows that temperature had a significant impact on survival rates of FAW immature stages. The highest egg hatching rate was (100%) at 35°C, followed by (86.67%) at both 25 and 30°C, and 76.67% at 20°C. Statistical analysis proved that there were significant differences in the rate of egg hatching among tested temperatures (F=2.750; P=0.112). The same trend was also observed for larval survival as the greatest value (86.67%) was recorded at 25°C and the lowest (76.67%) was recorded at 20°C, with significant differences among the tested temperature regimes (F= 0.396; P= 0.759). Regarding pupal survival, the greatest rate of survival (83.33%) was also observed at 25°C followed by 80% at 30°C and 76.67% at 35°C. Rates of pupal survival at 20°C were 60%. Indeed, significant differences did not exist in pupal period among treatments (F= 1.933; P= 0.203). The overall generation survival (egg-adult) was greatest (83.33%) at 25°C and lowest (70%) at 30 and 35°C. At 20°C, the generation survival rates were 60.00%. Clearly, significant differences were observed among the tested temperature regimes in terms of overall generation survival (F= 1.179; P= 0.377).

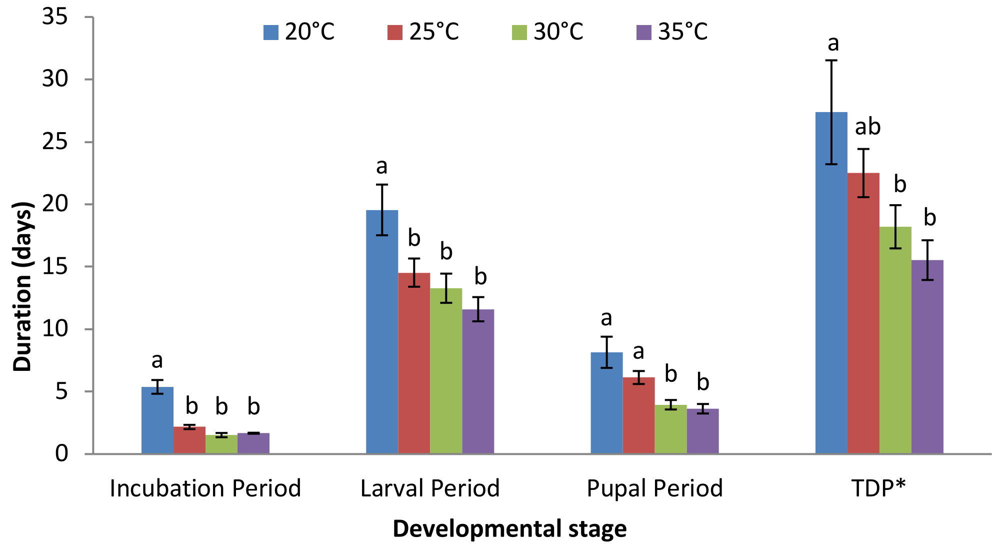


**Fig. (1):** Mean (day ± SE) of developmental periods of FAW reared on maize at different temperature regimes. Bars with different letters indicate significant difference (*P*< 0.05)

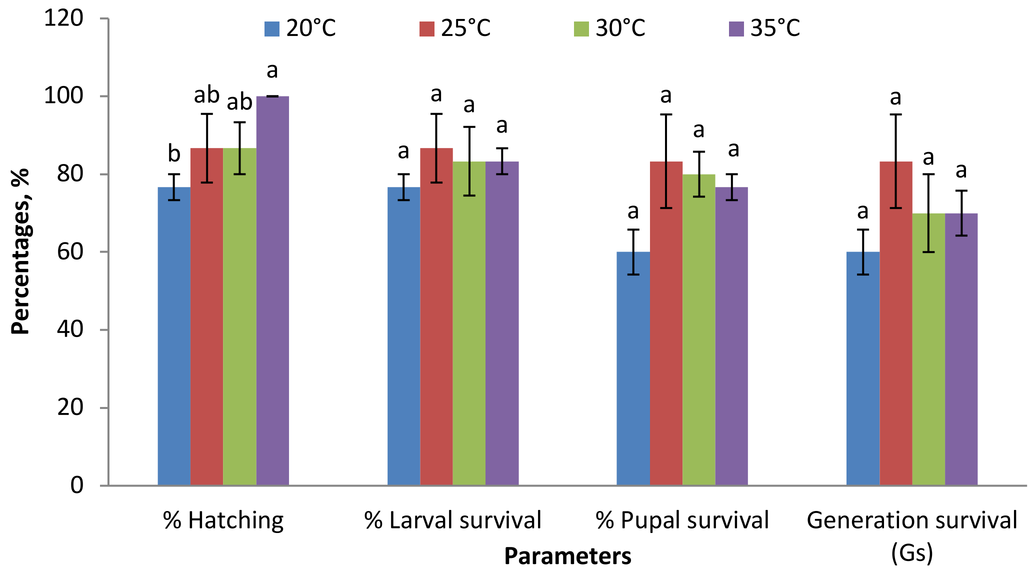


**Fig. (2):** Effect of different temperatures (20, 25, 30 and 35ºC) on rates of survival of FAW immature stages under laboratory conditions. Bars with different letters indicate significant difference (P<0.05).

**Effects on FAW adult stages**

**Effects on ovipositional periods:** Data in Figure (3) indicated that the respective pre-ovipositional periods were 8.50, 6.83, 3.00 and 2.58 days at 20, 25, 30 and 35°C. Significant differences were found among treatments in terms of pre-ovipositional periods (F=124.846; *P*=0.000). As for ovipositional period, the longest period was 9.83 days at 20°C, whereas the shortest one was 3.71 days at 35°C. At 25 and 30°C, these periods were comparable at 9.17 and 7.08 days, respectively. Obviously, there were significant differences among ovipositional periods under the tested temperatures (F= 60.26; P=0.000). Regarding post-ovipositional period, this interval was very short (1 day) at 35°C, increased to 1.33, 2.00 and 4.75 days at 30, 25 and 20°C, respectively. Statistical analyses revealed that significant differences among tested thermal treatments existed (F=18.495; P=0.000).

**Effects of temperatures on fecundity:** According to Figure (4), FAW females oviposited successfully under all tested temperatures. However, little number of eggs (223.5 and 237.08 eggs) was laid per female at 35, 20°C, respectively. Lifetime fecundity increased to 911.00 and 1547.08 eggs at 25 and 30°C, respectively. Obviously, temperature had significant effect on the total lifetime fecundity (F= 59.542; *P*=0.000). As for daily fecundity, the mean daily fecundity of FAW was 23.42, 66.17, 134.33 and 175.67 eggs/female at the respective temperatures. Clearly, there was significant difference among tested temperatures in terms of daily fecundity (F= 23.595; *P*=0.000).

**Effects on adult longevity:** In general, females of FAWs live longer than males regardless of rearing temperatures, as the longevity of either males or females decreased as temperature increased. Longevity of FAW females lasted 28.08, 17.58, 11.67 and 7.29 days at the respective temperatures (Fig. 5). Apparently, there were significant differences in terms of female longevity among tested temperatures (F=325.942; *P*=0.000). Pertaining to FAW males, their longevities at the respective temperatures were 23.33, 21.42, 13.00 and 5.92 days. Indeed, significant differences were found in male longevity among the tested temperatures (F=608.972; *P*=0.000).

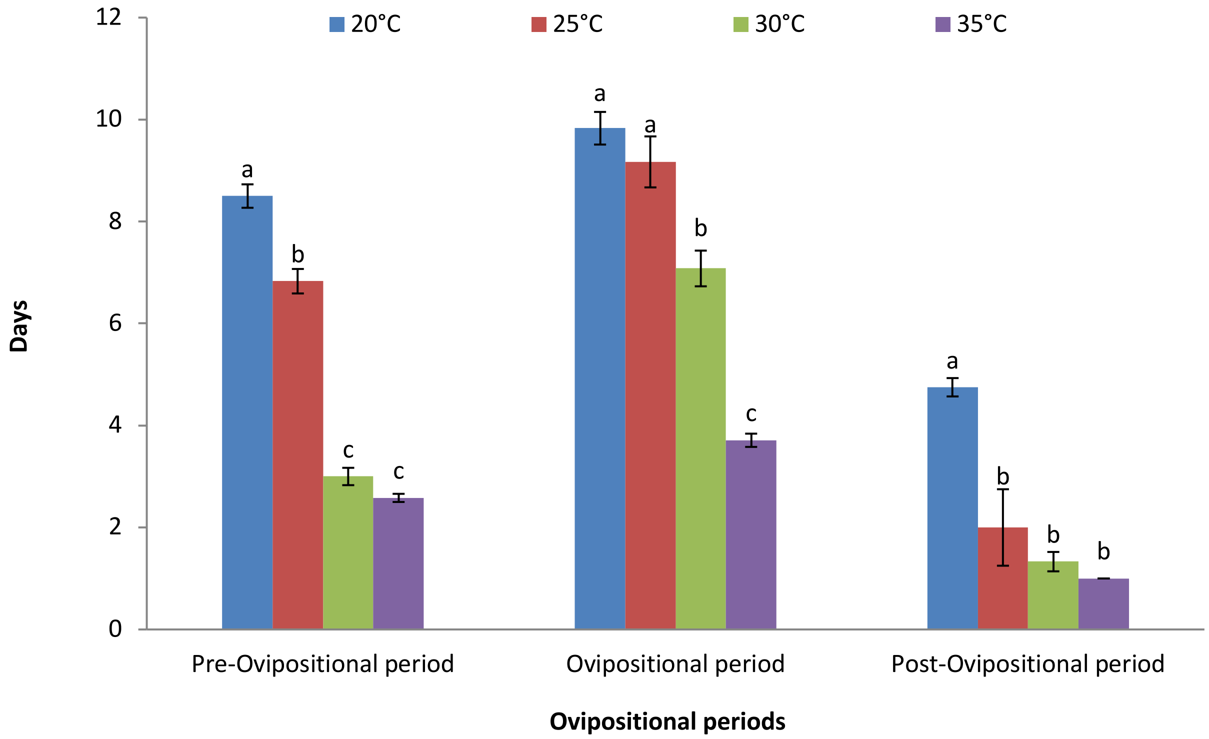


**Fig. (3):** Mean (day ± SE) of ovipositional periods of FAW reared on maize at different temperature regimes. Bars with different letters indicate significant difference (*P*<0.05).

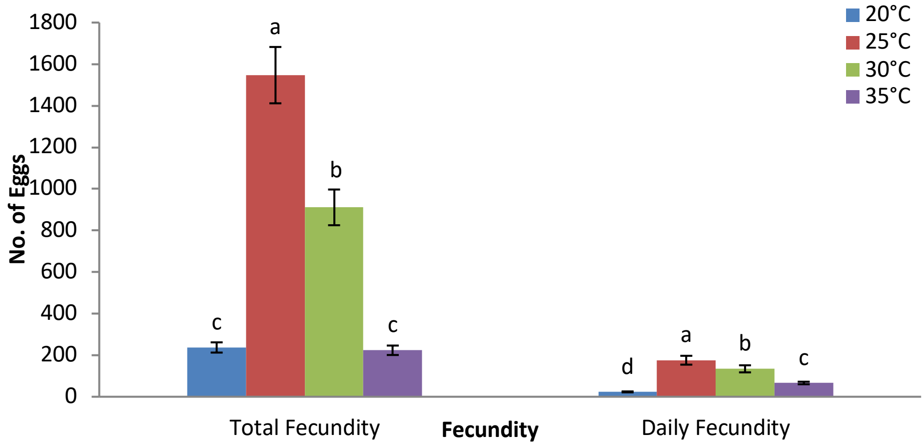


**Fig. (4):** Mean (±SE) of daily and total lifetime fecundity of FAW at different temperature regimes. Bars with different letters in the same treatment indicate significant difference (*P*<0.05).

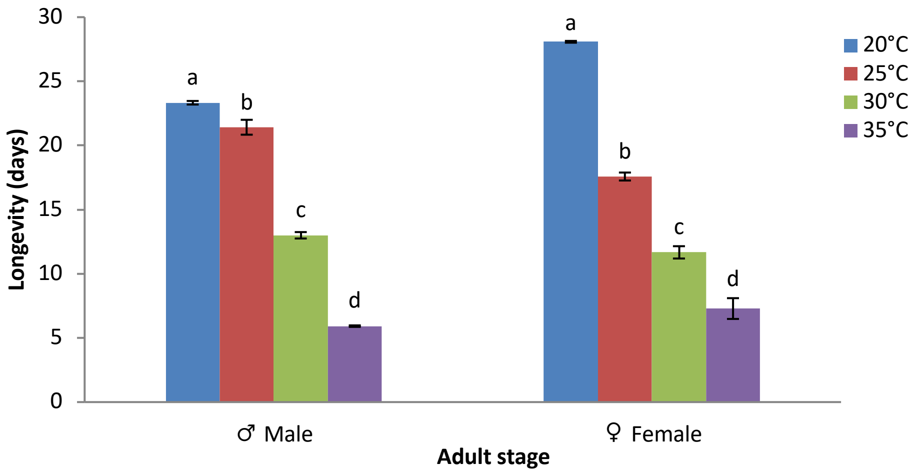


**Fig. (5):** Mean (±SE) of male and female longevity of FAW at different tested temperature regimes. Bars with different letters in the same treatment indicate significant difference (*P*<0.05)

## DISCUSSION

Temperature had a profound effect on the biological attributes of *S. frugiperda* evaluated in the current study. On the egg stage, there was a significant decrease in the incubation period as the tested temperature increased from 20 to 35 °C, which is relatively in line with the results of Ali *et al.* (1990) who reported a somewhat wider favorable range from 17 to 38 °C. Huang *et al.* (2021) recorded a significant reduction in incubation period from 7.5 days at 19 °C to 2.0 days at 31°C, while it was 1.33 and 14.25 days at 32 °C and 15°C, respectively (Malekera *et al.,* 2022). On the other hand, the high viability of *S. frugiperda* eggs observed in this study is consistent with results from previous studies (Montezano *et al.,* 2019; Du Plessis *et al.,* 2020). The same trend was also observed for the effect of temperature on the larval stage, as the larval development time decreased significantly with its increasing, while the highest larval survival rate was 86.67% at 25°C and the lowest was 76.67% at 20 °C. The results obtained regarding the duration of larval development as well as the survival rate were similar to those reported earlier by Ali et al. (1990) and Garcia *et al.* (2018). As for pupal stage, the duration of pupal development of FAW in the current study ranged between 3.63 days at 35°C to 8.15 days at 20°C, which was faster than those of Du Plessis et al. (2020) who recorded that it ranged between 7.82 and 30.68 days at 32 and 18 °C, respectively. The results also indicated that high pupal survival rate was 83.33% at 25 °C, while the lowest was 60% at 20°C, which is not consistent with those obtained by Huang et al. (2021) who recorded higher larval and pupal survival rates (more than 96% and 86%, respectively, at 22, 25, 28, and 31°C).

In this study, the total developmental time of *S. frugiperda* immature stages was 27.37, 22.50, 18.20 and 15.53 days at 20, 25, 30 and 35 °C, respectively. These findings are in harmony with those of Du Plessis et al. (2020) who reported that the developmental time from egg to adult was inversely related to temperature and the optimal range was between 26 and 30°C. Also, Ali *et al.* (2023) found that the duration of the overall developmental period of FAW immatures (egg to adult) was 27.37 and 30.73 days for females and males, respectively at 27±2 °C and 65±5% RH on maize in a greenhouse. Huang *et al.* (2020) recorded less time to complete a generation (e.g., 20 days at 31°C compared with 23 days at 30 °C). Barfield et al. (1978) found that the mean total developmental time ranged from 66.6 days (15.6 °C) to 18.4 days (35.0°C). As for the overall generation survival, significant differences among tested temperatures were recorded, ranging between 60% at 20 °C, 70% at 30, 35 °C and 83.3% at 25 °C, which indicating that the species can easily adapt to a new environment wherever it (Huang et al., 2020). As for the reproduction parameters of adult stage, temperature significantly influenced the duration of ovipositional periods as well as the number of laid eggs and longevity. Data obtained revealed that the longest female lifespan (28.08 days) was recorded at 20°C, while the shortest (7.29 days) was observed at 35°C. These results were very similar to those obtained by Garcia et al. (2018) who concluded that the temperature inversely affected the longevity of the adults, ranging from 8.8 d at 30°C to 19.5 d at 18°C. Also, the longest ovipositional period was 9.83 days at 20°C, whereas the shortest was 3.71 days at 35°C. These results are close to those of Huang (2021), who found that FAW females laid eggs for more than 20 days and up to 72.30 and 90% of these eggs were deposited during the first 5 and 10 days, respectively. Temperature also influenced the lifetime fecundity of FAW fed on maize in laboratory. These findings were in consistence with those reported earlier by Chen *et al.* (2022) who proved that higher temperatures increased FAW fecundity when fed on maize.

## CONCLUSIONS

The obtained results in this study demonstrated that temperature has a profound influence on the development of all immature stages, survival, adult longevity and reproduction of FAW. As the temperature increased, there was a significant decrease in immature developmental duration and longevity. Likewise, temperature had significant effect on the total lifetime fecundity of FAW. Which clearly was observed at temperature ranged between 25 and 30°C. These results should be taken into consideration when developing an integrated pest management (IPM) strategy for its control, since it can be useful in predicting pest outbreaks and might provide information on its population dynamics.

## REFERENCES


Ali, A., Luttrell, R.G. and Schneider, J.C. 1990. Effects of temperature and larval diet on development of the fall armyworm (Lepidoptera: Noctuidae). Annals of the Entomological Society of America, 83(4): 725-733.

Ali, M. P., Haque, S. S., Hossain, M. M., Bari, M. N., Kabir, M. M. M., Roy, T. K. ... & Krupnik, T. J. 2023. Development and demographic parameters of Fall Armyworm (Spodoptera frugiperda JE Smith) when feeding on rice (Oryza sativa). *CABI Agriculture and Bioscience*, *4*(1): 1-14.

Assefa, F. and Ayalew, D. 2019. Status and control measures of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Ethiopia: A review. Cogent Food & Agriculture, 5(1): 1641902.

Barfield, C.S., Mitchell, E.R. and Poeb, S.L. 1978. A temperature-dependent model for fall armyworm development. Annals of the Entomological Society of America, 71(1): 70-74.

Briere J.F., P. Pracros, A.Y. Le Roux and J.S. Pierre. 1999. A novel rate model of temperature-dependent development for arthropods. Environ. Entomol, 28:22-29.

Chen, Y.C., Chen, D.F., Yang, M.F. and Liu, J.F. 2022. The effect of temperatures and hosts on the life cycle of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Insects, 13(2): 211.

Du Plessis, H., Schlemmer, M.L. and Van den Berg, J. 2020. The effect of temperature on the development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Insects, 11(4): 228.

FAO 2022. FAOSTAT: Production: Crops and livestock products. In: FAO. Rome. Cited October 2022. https://www.fao.org/faostat/en/#data/QCL

Garcia, A.G., Godoy, W.A.C., Thomas, J.M.G., Nagoshi, R.N. and Meagher, R.L. 2018. Delimiting strategic zones for the development of fall armyworm (Lepidoptera: Noctuidae) on corn in the state of Florida. Journal of economic entomology, 111(1): 120-126.

Honek A. 1999. Constraints on thermal requirements for insect development. Entomol Sci, 2:615-621.

Huang, L.L., Xue, F.S., Chen, C., Guo, X., Tang, J.J., Zhong, L. and He, H.M. 2021. Effects of temperature on life history traits of the newly invasive fall armyworm, *Spodoptera frugiperda* in Southeast China. Ecology and Evolution, 11(10): 5255-5264.

Huang, Y., Dong, Y., Huang, W., Ren, B., Deng, Q., Shi, Y., Bai, J., Ren, Y., Geng, Y. and Ma, H. 2020. Overwintering distribution of fall armyworm (*Spodoptera frugiperda*) in Yunnan, China, and influencing environmental factors. Insects, 11(11): 805.

Huey, R.B. and D. Berrigan. 2001. Temperature, demography, and ectotherm fitness. *The American Naturalist,* 158:204–210.

Huffaker, C., A. Berryman and P. Turchin. 1999. Dynamics and regulation of insect populations. In *Ecological entomology*, ed. Huffaker, C.B. and A.P. Gutierrez, 269–305. New York: Wiley.

Infante, F. 2000. Development and population growth rates of *Prorops nasuta* (Hym., Bethylidae) at constant temperatures. *Journal of Applied Entomology* 124: 343–348.

Malekera, M.J., Acharya, R., Mostafiz, M.M., Hwang, H.S., Bhusal, N. and Lee, K.Y. 2022. Temperature-Dependent Development Models Describing the Effects of Temperature on the Development of the Fall Armyworm *Spodoptera frugiperda* (JE Smith)(Lepidoptera: Noctuidae). Insects, 13(12): 1084.

Matova, P. M., Kamutando, C.N., Magorokosho, C., Kutywayo, D., Gutsa, F. and Labuschagne, M. 2020. Fall-armyworm invasion, control practices and resistance breeding in Sub-Saharan Africa. Crop science, 60(6): 2951-2970.

Montezano, D.G., Sosa-Gómez, D.R., Specht, A., Roque-Specht, V.F., Sousa-Silva, J.C., Paula-Moraes, S.D., Peterson, J.A. and Hunt T.E. 2019. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. African entomology, 26(2): 286-300.

Ratte, Hans T. 1985. Temperature and insect development. In: Hoffmann KH (ed) *Environmental physiology and biochemistry of insects*. Springer Berlin Heidelberg, 33-66.

SPSS, I. (2013). IBM SPSS statistics for windows. Armonk, New York, USA: IBM SPSS, 2, 119.

# تأثير درجة الحرارة علي بعض السمات البيولوجية لدودة الحشد الخريفية، *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera; Noctuidae)، علي الذرة

**ليلي علي مراد، ناصر سعيد مندور، محمد عبدالنعيم عثمان، كريمان محمود محمد، محمد علي عبدالهادي**

قسم وقاية النبات – كلية الزراعة – جامعة قناة السويس – الإسماعيلية – مصر

**المستخلص**: منذ اكتشاف دودة الحشد الخريفية (FAW)، *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae)، كآفة غازية غريبة جديدة في مصر في نهاية عام2019، أصبحت الآفة الأكثر تدميراً من الناحية الاقتصادية لمحصول الذرة في مصر نظراً لصعوبة السيطرة عليها ومكافحتها. وتهدف الدراسة الحالية إلي دراسة تأثير أربع درجات حرارة مختلفة (20، 25، 30، 35±1 درجة مئوية) على الخصائص البيولوجية لدودة الحشد الخريفية. أظهرت النتائج تاثيراً سلبيا" علي طول فترة نمو الأطوار غير الكاملة مع زيادة درجات الحرارة، حيث كانت أطول فترة نمو للأطوار غير الكاملة 37.27 يوم علي درجة حرارة 20 درجة مئوية، بينما كانت أقصر فترة نمو15.53 يوم علي درجة حرارة 35 درجة مئوية. كما أشارت النتائج ايضا أن لدرجة الحرارة تأثير معنوي علي معدل بقاء جميع الأطوار غير الكاملة لدودة الحشد الخريفية. وقد كان لدرجات الحرارة تأثير معنوي علي خصوبة الإناث، حيث بلغ المتوسط اليومي لعدد البيض الذي تضعه الأنثي الواحدة يومياً 42.23 و 17.66 و 33.134 و 175.67 بيضة علي درجات الحرارة 20 و 35 و 30 و 25 درجة مئوية على الترتيب. كما لوحظ قصر فترة حياة الأطوار الكاملة سواء الذكور أو الإناث بزيادة درجات الحرارة. وكانت أعلي نسبة بقاء (83.33٪) عند 25 درجة مئوية وأقلها كانت (70٪) عند 30 و 35 درجة مئوية، بينما بلغت 60٪ عند 20 درجة مئوية. ولذلك فإن درجة الحرارة المثلى لنمو تعداد دودة الحشد تتراوح بين 25 إلى 30 درجة مئوية.