SVU-IJAS
SVU-International Journal of Agricultural Sciences
Volume 6 Issue (3) pp.: 107-120, 2024
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2024.305807.1381

Check for updates

RESEARCH ARTICLE

Insights into the Biological Aspects and Cannibalistic Behavior of Fall Armyworm (*Spodoptera frugiperda*) under Constant Temperature Conditions

Abd -ElGalil, Doaa M. [1], M.M.S. Bakry [2], Ghada S. Mohamed [1]*, and M.A. Ali [1]

[1] *Plant Protection Department, Faculty of Agriculture, South Valley University, 83523 Qena, Egypt.*
[2] *Department of Scale Insects and Mealybugs Research, Plant Protection Research Institute, Agricultural Research Center, 12619 Giza, Egypt.*

Abstract

This study investigated the impact of constant temperature(30±1ºC) on the developmental stages of the fall armyworm (FAW), *Spodoptera frugiperda*, and explored cannibalism behavior during the larval phase. The results revealed that FAW female exhibited an average fecundity of 696 eggs, ranging from 494 to 984 eggs during their entire lifespan. The pre-oviposition and oviposition periods averaged 2.66 and 1.33 days, respectively. Male and female longevity were 9 and 10 days, respectively. The egg incubation period was 1.35 days, with a hatching rate of 83.3%. Larval development took an average of 13.5 days, with the highest mortality rate observed in the 3rd instar (30%) and the lowest in the 6th instar (3.3%). Pupal development lasted 7.4 days, with an average pupal weight of 0.167 g and a 3.3% mortality rate. The complete life cycle (from egg to egg) averaged 37 days. Cannibalism occurred across all larval stages of the same age, peaking in the 4th larval instar on both maize (4.72±0.47) and castor leaves (1.75±0.25). The lowest cannibalism rate was observed in the 6th larval instar. Cannibalism increased with reduced food and smaller container sizes. This study provides crucial insights into the biological aspects and cannibalistic behavior of *S. frugiperda*, aiding in the development of integrated pest management strategies against this invasive species in Egypt.

Keywords: *S. frugiperda*, FAW, Biological aspect, Fecundity, Mortality, Maize, Cannibalism.

1. Introduction

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), poses a substantial threat to economic crops, particularly cereal crops, due to its polyphagous nature and wide host range encompassing over 353 plant species (Casmuz *et al*., 2010; Montezano *et al*., 2018). Economic crops such as maize, sorghum, rice, sugarcane, wheat, cotton, and various vegetables are among their targeted hosts (He *et al*., 2022; Wu *et al*., 2021). Its geographic distribution spans several countries in South America and the USA (Prowell *et al*., 2004; Bueno *et al*., 2010; Padhee & Prasanna, 2019).
The fall armyworm caused a significant incursion into West Africa in 2016 (Goergen *et al*., 2016) and subsequently expanded its presence across extensive areas of sub-Saharan Africa and North Africa (Day *et al*., 2017; Cock *et al*., 2017). The first occurrence of fall armyworm in Egypt was reported in May 2019 in the maize fields of a village in Kom Ombo city, Aswan Governorate, Southern Egypt (Dahi *et al*., 2020). Due to its damage behavior, it causes high economic loss (Ali *et al*., 2023) This invasive presence of *S. frugiperda* in Egypt necessitates a comprehensive exploration of its biology within the Egyptian ecosystem for the development of effective pest control strategies.
However, studying the biology of fall armyworm larvae presents a unique challenge due to their

***Corresponding author: Ghada S. Mohamed**
Email: d.ghada1@yahoo.com
Received: July 20, 2024; Accepted: August 17, 2024; Published online: August 25, 2024.

inherent cannibalistic tendencies (Chaman *et al*., 2000). Cannibalism, defined as the act of killing and consuming specific individuals, is a distinctive behavior observed in various animal species, including insects (Fox, 1975). The literature reveals instances of cannibalistic behavior among fall armyworm larvae in both field and laboratory conditions (Raffa 1987; Chapman *et al*. 1999a; 1999b; 2000). Cannibalism is particularly pronounced under conditions of reduced food availability and high population density (Richardson *et al*., 2010; Vangansbeke *et al*., 2014; Murata *et al*., 2023). Larger larvae tend to exhibit cannibalistic behavior, often targeting smaller larvae, especially when facing nutritional deficits (Bentivenha *et al*., 2017; D'amico *et al*., 2021).

The adaptive nature of cannibalism, providing growth and developmental advantages to the cannibalistic larvae, has significant implications for the understanding of fall armyworm ecology (Ren *et al*., 2020). While cannibalism may contribute to reducing the fitness of potential natural enemies, it can complicate biological control methods by depleting available resources and compromising the quality of these resources (Prasad & Prasad, 2018). Importantly, cannibalism among same-aged larvae, particularly in immature instars, remains insufficiently studied, although addressing this gap is crucial for effective pest control strategies targeting early instars (Ren *et al*., 2020).

This study seeks to elucidate the intricacies of cannibalistic behavior within same-aged larval instars of fall armyworms and investigate the influence of density and food quantity on such behavior under controlled laboratory conditions. The findings are anticipated to contribute to the development of nuanced and effective pest management strategies tailored to the specific ecological conditions in Egypt.

2. Materials and methods

2.1. Rearing of fall armyworm, S. frugiperda

2.1.1. S. frugiperda Stock Colony:

FAW, *S. frugiperda* larvae were collected from an infested maize field on 16 May 2023 in Esna city, Luxor governorate (25°16'57.2N 32°32'45.9 E), and transferred to the insect laboratory of the Plant Protection Department, Faculty of Agriculture, South Valley University. These larvae were reared in plastic containers (370 ml, 10.5cm height × 5.5 cm diameter) with air - permeable lids and provided with maize leaves as food and replaced daily. Larvae were reared individually from the 4^{th} instar onwards. was in the same plastic containers. Larvae were kept in a rearing at 30 ± 1°C and 65 ±5% RH until pupation. Pupae were emergencies and kept in the same rearing as the larvae. Pupae were observed daily until moths emerged.

After the emergence of moths, a pair of male and female were confined in plastic containers (30 cm height ×12.5 cm diameter) for rearing, and they were kept in the same conditions. A plastic container was cut open from the side and provided with a piece of cotton soaked in a 10% sugar solution described by (Tian *et al*., 2020), and provided with a maize plant, 10-15days old, which was grown in the plastic cup until the female lay eggs on it. The plastic containers were covered with a fine of tulle to prevent moths from escaping. The maize leaves and stems were replaced daily and inspected for egg masses.

2.1.2. Egg stage

Egg masses from the stock colony were removed from maize plants within 24 hours of oviposition by cutting the piece of leaf to which the egg masses were attached. The eggs were transferred to plastic cups (10.5×5.5 cm), and incubated in the same conditions. Four replicates of 10 eggs/replicate were checked daily until hatching.

2.1.3. The larval and pupal stage

Eggs were collected from moths kept in the same conditions. After hatching, neonate larvae were transferred and kept collectively, three replicates (each of 10 larvae), in the plastic containers (10.5×5.5cm), and they were covered with a piece of cloth with narrow holes, as the larvae are not escape, and provided daily with fresh maize leaves as food. The larvae from 4th instar were reared individually. Once the larvae pupate, the pupae remain in the same container under the same conditions of constant temperature and humidity as described above, and checked daily until the emergence of the moths.

2.2. Cannibalism

2.2.1. Experiment the cannibalism between larvae of the same age

Cannibalism with larvae at the same age under laboratory conditions (30 ± 1°C and 65 ±5% RH). Twenty larvae of each instar stage were randomly selected from the rearing colony and divided into 4 replicates for each instar stage. Larvae were placed inside plastic containers (30 cm in height and 12.5 cm in diameter) equipped with a ventilated lid, and the larvae were fed a diet divided into two groups (types of food), which were either maize leaves (main host) or castor leaves, to determine whether the food had an effect on the rate of cannibalism, the food was replaced daily. The feeding rate and leaf consumption of FAW larvae were determined by weighing leaves ingested by individual larvae at each age stage and weighing them before and after 24 hours feeding period using a digitally sensitive balance with one decimal place. A sufficient quantity of fresh maize and castor leaves were provided every 24 hours during the experimental period. The remaining larvae were recorded, and it was assumed that the missing larvae had been cannibalized every 24 hours.

The average cannibalism= $\frac{\text{Dividing the number of cannibalistic larvae}}{\text{Number of larvae that were initially present}}$.

2.2.2. Experiment the food quantity

In this experiment, we studied the relationship between food quantity and cannibalistic behavior at the fourth and fifth larval instars. FAW larvae used in the experiment were collected separately from colonies rearing in the laboratory under the same conditions mentioned above. The larvae were transferred in groups consisting of 5 individuals for each instar stage in plastic containers (30 cm in height and 12.5 cm in diameter) according to the amount of food at 0.1, 0.2, and 0.4 g/larva and that for each larval instar and amount of food, 4 replicates were done for each treatment. The food source was fresh corn leaves, identical to the feeding system used in mass rearing, and checked daily to record the number of larvae that were cannibalized and replaced with food.

2.2.3. Experiment the difference in space size

The experiment consisted of 90 larvae that were randomly selected for both the fourth and fifth larval instar from the rearing colonies, divided into three groups according to the available space: small (10 length, 7.5 width, and 6 depth cm), medium (14 length,11 width, and 5 depth cm), and large (19 length, 15 width, and 7.5 depth cm) plastic containers with holes at the top to allow ventilation and provide the larvae with maize leaves. This was done to determine if space affects the cannibalism rate. The larvae were placed in groups of 10 larvae in each plastic container, and each treatment was repeated 3 times, depending on the area of the container providing each instar larvae with enough food. The number of cannibalistic larvae in each plastic container was recorded until the larvae molted to the next instar.

2.3. Data analysis

The duration of the various stages was calculated (incubation period, larval duration, larval mortality, larval pupation, pupal duration, pupal weight, sex ratio, pre-oviposition period, oviposition period, post-oviposition period, fecundity, number of egg masses, number of eggs per mass, adult longevity, cannibalism rate at each instar within the same age, and cannibalism at different spaces and different amounts of food). All data obtained in this study were subjected to data analysis by means of standard errors. Differences in each A parameter measured by one-way analysis of variance (ANOVA) through software (GraphPad Statistical version 6.01).

3. Results and discussion

3.1. Biological studies

3.1.1. Incubation period of eggs

Females lay eggs in several shapes, either in the form of masses, patches, or clusters of pale green or creamy white eggs that turn brown when hatched. The eggs are covered with gray, white scales or not covered. Data in Table (1) show that the mean of incubation periods was 1.35 ± 0.1457 days and the mean percentage of egg hatching was 83.3%. Figure (1) shows the different behavior of female *S. frugiperda* eggs.

Table 1. Incubation period and hatchability percent of *S. frugiperda* egg stage at 30°C.

Biological aspect	Mean ± SE	Range
Incubation period (days)	1.35±0.15	1-3
Hatchability (%)	83.33 ± 6.92	80-100%

Figure 1. Different oviposition behavior of female *S. frugiperda* under laboratory conditions.

3.1.2. Development of larval stage

Through the rearing of larval stages and the follow up of the molting process, 6 different larval instars were recorded. These larval stages development took an average of 13.6 days before turning to the pupal stage shown in Table (2). The same table indicated the mean of mortality for the larval ages, where the mortality was highest in the 3rd instar 30%, and lowest in the 6th instar 3.33%. The percentage of pupation resulting from the 6th instar larvae was 96.67%.

Table 2. Mean and range duration of development of the larval stage (days) and mortality (%) of *S. frugiperda.*

Parameters	Mean ± SE	Range	Mortality% Mo
1st instar	1.33 ± 0.17	1-2	23.30
2nd instar	2.33± 0.17	2-3	23.30
3rd instar	2.83±0.17	2-4	30
4th instar	1.43± 0.09	1-2	20
5th instar	2.20± 0.12	2-3	6.60
6th instar	2.63± 0.18	2-3	3.33
Total larvae	13.5	10-17	

3.1.3. Duration of pupal stage

The sixth larval instar stopped feeding in the pre-pupal stage and began to form cocoons from soil grains. The pupal stage was completed within a mean period of 7.40 days. The average pupal weight was recorded as 0.17, and the percentage of pupal mortality was 3.33% as shown in Table (3).

Table 3. Pupal duration, weight, and mortality (mean ± standard error) of *S. frugiperda*.

Biological aspects	Mean ± SE
Pupal duration(days)	7.40 ±0.18
weight(g)	0.17±0.02
mortality (%)	3.33±3.33

3.1.4. Duration of Adult Stage

Data in Table (4) showed results of the male and female longevity and biological parameters of females. female lives an average of 10 days compared to the male, which lives an average of 9 days. At the same time, the mean time required for maturation of the ovaries and starting to lay eggs (pre-oviposition period), post-oviposition period, and between two oviposition were 2.67, 1.67, and 1.33 days, respectively. The results indicate that the fecundity (no. of eggs/female), no. of eggs/mass, and no. of egg mass were 696, 97.5, and 18.33, respectively. The sex ratio of *S. frugiperda* was approximately (16 ♂:14♀).

Table 4. Biological aspects of *S. frugiperda* adult stage reared in the laboratory at constant conditions.

Biological aspects	Statistics	
	Range	Mean ± SE
No. of egg/female (fecundity)	494- 984	696±135.70
No. of mass/female	10- 27	18.33±4.91
No. of egg/mass	5-190	97.5
Pre-oviposition(days)	2- 4	2.667±0.67
Post-oviposition period(days)	2- 4	2.67±0.33
Between two positions(days)	1-2	1.33±0.33
First egg (days)	2-4	2.667±0.67
Last egg (days)	9-11	10±0.58
Male longevity(days)	9	9±00
Female longevity(days)	9- 11	10±0.58
Sex ratio ♂: ♀	16:14	1.14: 1

3.2. Cannibalism

This experiment was conducted to determine cannibalistic behavior within larval instars of the same age, studying the effect of density, and food quantity on cannibalistic behavior under laboratory conditions.

3.2.1. Cannibalism within larval of the same age

Data in Figure (2) showed the cannibalism rate among larvae of the same age when rearing on castor and maize leaves. When rearing *S. frugiperda* larvae on castor plant leaves, both the first and second instar larvae exhibited a lower cannibalism percentage of 25%, whereas the fourth instar larvae recorded the highest cannibalism rate at 35%. The third and sixth instar larvae each recorded a cannibalism rate of 30%.

S. frugiperda larvae showed a higher rate of cannibalism when feeding on maize leaves, where the sixth larval instar recorded the lowest rate of cannibalism, 25%, the fourth larval instar showed the highest rate of cannibalism, 55%, and both the third and fifth larval instar showed a rate of 45%. There are no significant differences between the rates of cannibalism of larvae (P value = 0.07) when rearing on maize or castor leaves, as shown in Table (5).

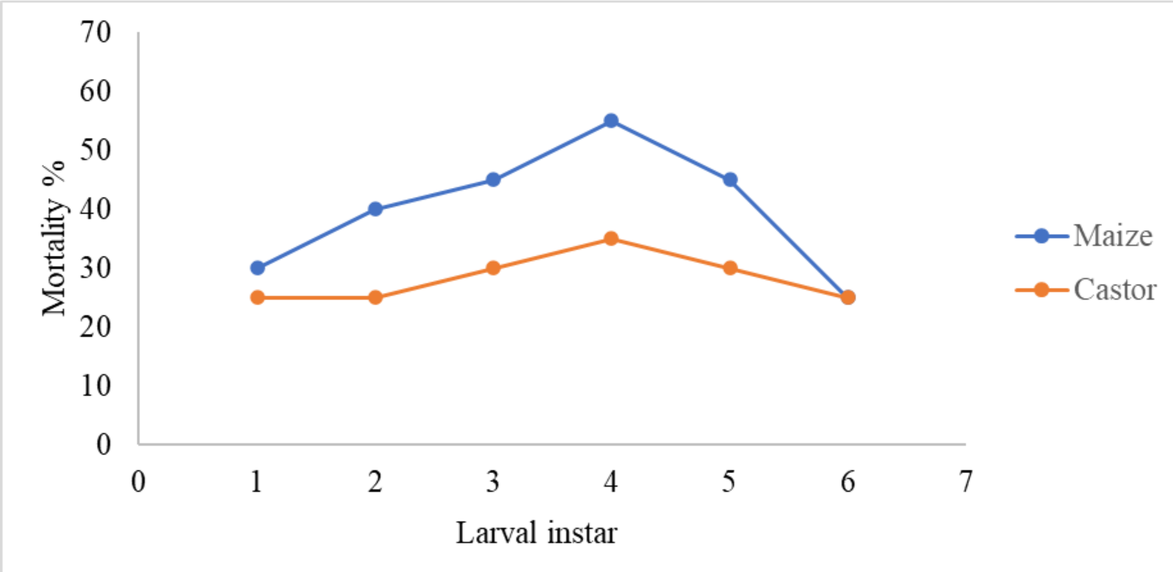

Figure 2. Percentage of cannibalism behavior among *S. frugiperda* larvae of the same age on different plant hosts under laboratory conditions.

Table 5. Cannibalism proportions of the different larval instar of *S. frugiperda* for different plant hosts (mean± SE).

Instar larval	Maize	Castor	P value
First instar	1.5 ± 0.28	1.25 ± 0.25	0.08
Second instar	2 ± 0	1.25 ± 0.25	
Third instar	2.25 ± 0.25	1.5 ± 0.28	
Fourth instar	2.75 ± 0.47	1.75 ± 0.25	
Fifth instar	2.25 ± 0.47	1.5 ± 0.28	
Sixth instar	1.25 ± 0.62	1.25 ± 0.47	

3.2.2. Relationship between food quantity on cannibalism in S. frugiperda larvae

Cannibalism in *S. frugiperda* larvae showed a non-significant difference between the amount of food in the evaluated instars, as shown in Table (6). At 4th larval instar, the rate of cannibalism in larvae was higher when the amount of food decreased, and with an increase in the amount of food, cannibalism decreased from 60 to 45%. As for 5th larval instar, the rate of cannibalism was recorded lower than that of 4th larval instar, where 50% cannibalism was recorded at an amount of 0.5 g, and at 2 g recorded 40%. The data is shown in Figure (3).

Table 6. Mean number of cannibalism larvae (mean ±SE) on exposed to different food amounts of *S. frugiperda* larvae.

	Quantity of food			P value
	0.5 g	1 g	2 g	
Fourth larval instar	3± 0.41	2.50± 0.29	2.25 ±0.49	0.51
Fifth larval instar	2.50 ±0.29	2.25 ±0.478	2 ±0	

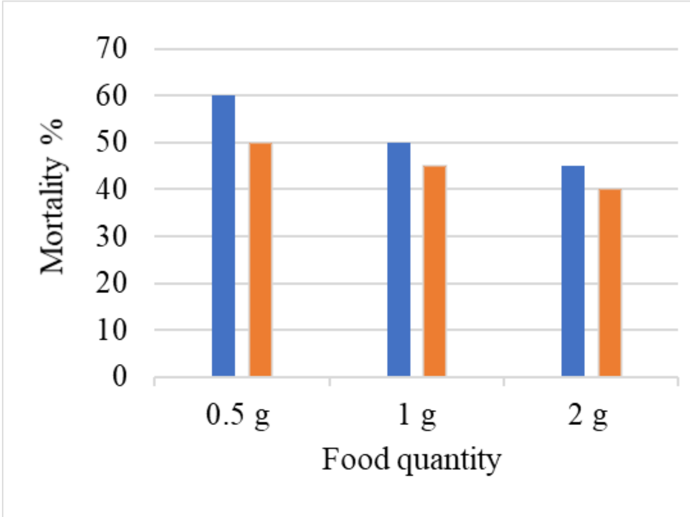

Figure 3. The percentage of cannibalism in the fourth and fifth instar larvae feeding at different food amounts of maize.

3.2.3. Effect of different size space on cannibalistic behavior in S. frugiperda larvae

The results data in Table (7)show that there was no significant relationship between larval density and cannibalism at the ages evaluated. Larval cannibalism was higher in small areas for both the fourth and fifth larval instars, where fourth and fifth larval instar cannibalism recorded 46.6 and 66.6%, respectively. However, when more space was provided, the cannibalism rate decreased to 36.6 for the fourth instar and 46.6% for the fifth instar, and these data are shown in Figure (4).

Table 7. Cannibalistic Behavior of Fourth and Fifth Instar *S. frugiperda* Larvae in Response to Varied Spatial Densities (mean ± SE)

Density	Fourth	Fifth	P value
Small	4.66±0.33	6.66 ± 0.88	
Medium	4.33 ± 0.33	5.33 ±0.88	0.34
Large	3.66 ±0.33	4.66 ±1.76	

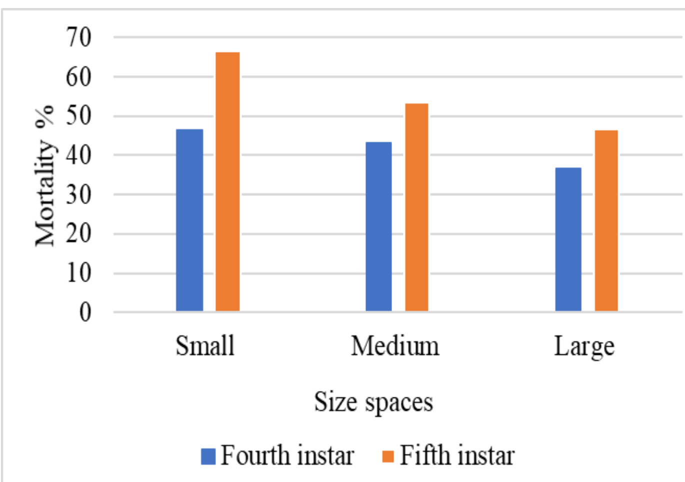

Figure 4. Percentage mortality of *S. frugiperda* larvae at places of different size.

Figure 5. Cannibalistic behavior among *S. frugiperda* larvae of the same age.

4. Discussion

The biological study revealed that the incubation period of eggs is between 1-3 days ,with an average of 1.35 days. These results are consistent with the results found by Malekera *et al*. (2022), who recorded an average incubation period of eggs 1.50 days, and Chen *et al*. (2022) recorded 1.61 days of incubation period. There are also many previous results that found an average incubation period of 2 days (Schlemmer, 2018; Garcia *et al*., 2018; Du Plessis *et al*., 2020; Hong *et al*., 2022). Dahi *et al*. (2020), who recorded an average incubation period of 2.1 days.

According to the results of the current study, the average percentage of eggs hatching was 83.8%. Regarding the rate of egg hatching in our study, it seemed to be less than the study by Hong *et al*. (2022), who recorded a hatching rate of 91%, and Savadatti *et al*. (2023), reported the rate of hatching eggs at 90% .These differences between the results may be due to differences in humidity and the photoperiod.

The results in the current study showed that the average period of larval development was 13.5 days, ranging from 10to 17 days. These results are consistent with the results reached by many previous studies, as Schlemmer (2018) and Du Plessis *et al*. (2020), found the larval development ranges from 10-14 days, Hong *et al*. (2022), reported the duration of larval development ranged from 10-16 days, Malekera *et al*. (2022) reported the average duration of larval development was 12.64 days, and Savadatti *et al*. (2023) recorded the mean of development larval stage of 13.06 days. Our results differ from the results recorded by Dahi *et al*. (2020), who found that the average duration of larval stage development was 18.6 days. These differences between the results may be due to the different plant host used to feed the larvae.

The results of the study showed that the average percentage of larval mortality was lower in 6th larval instar, 3.3%, while the highest percentage of mortality in 3rd instar was 30%, and mortality in 1st and 2nd instar was equal, 23.3%, and in 4th instar, 20%, and in 5th was 6.6%, with an average mortality rate of 17.8%. These results are different from the results recorded by Chen *et al*. (2022) who recorded the average mortality rate was 0 at 1st, 3rd, and 4th larval instars, and the average mortality rate at 2nd larval instar was 0.02, and 5th larval instar was 0.05. Our results are similar to the results by Savadatti *et al*. (2023) who obtained a percentage of larval mortality of 22%. The higher rate of larval mortality in this study than in previous studies may be due to rearing larvae in small areas.

The results of this study indicated that the average duration of the pupal stage at 30 °C was 7.4 days. This is consistent with the results recorded in several previous studies at the same temperature, the average duration of pupal stage 7.7 days by Dahi *et al*. (2020), 7.5 days by Malekera *et al*. (2022), 7.6 days by Chen *et al*. (2022), 7.9 days by Hong *et al*. (2022), and Savadatti *et al*. (2023), recorded that the mean duration of pupal development 7days. The results recorded in this study were less than the duration of pupal development recorded by Du Plessis *et al*. (2020), who recorded that the average duration of this period was 9 days.

Considering the weight of pupae in this study, the average weight of pupae was 0.17g .These results agree with Malekera *et al*. (2022), who found that the weight of pupa ranged from 0.15 to 0.17g. The results of this study indicated that an average mortality rate for pupae was 3.3%, and this contradicts the results obtained by Chen *et al*. (2022), who found that there is no mortality of pupal stage at 30°C. It is possible that the presence of pupal stage mortality in this study is due to the occurrence of pupation in dry, not wet soil, which led to some pupae not emerging.

Regarding the results of fecundity(egg/female) of *S. frugiperda*, the number of eggs per female ranged from 494 to 984 eggs, with an average of 696 egg/ female. This is somewhat similar to the results reached by Garcia *et al*. (2018), who recorded that the average number of eggs/female was 790.10 eggs. The results of this study were in conflict with the results recorded by Saker *et al*. (2021), who reported the fecundity of females averaged at 355.2 egg/female, which is the lowest rate ever recorded at a temperature of 30°c, Chen *et al*. (2022), recorded an average female fecundity of 956.83eggs, and Hong *et al*. (2022), recorded the number of eggs/ female was 1400.50, which is the highest female fecundity rate observed at 30°c. These differences between the results may be due to differences in humidity and the photoperiod

From the current study, the results for the first and last egg laying (preoviposition and post oviposition) were laid by the adult female indicated an average of 2.66 days, and the duration between each egg laying and the next was recorded as an average of 1.3 days. These results agree with the results of Saker *et al*. (2021), recorded that the mean duration of pre-oviposition was 2.05 days, post-oviposition was 1.05 days, while occurred oviposition period was 4.05 days. Dahi *et al.* (2022), who recorded mean of pre-oviposition period was recorded at 2.1 days, Chen *et al*. (2022), who found the average pre- oviposition duration was at 2.17 and the oviposition period was 2.61 days, and Hong *et al*. (2022), recorded the pre-oviposition and oviposition duration an average of 3.33 days. While Garcia *et al*. (2018), recorded the highest average duration of the pre-oviposition and oviposition were 4.8 and 5.2 days, respectively at 30°c.

In our study, the average male longevity was 9 days and that of the female longevity was 10 days. This is considered the highest average recorded for *S. frugiperda* adults at 30°c compared to previous studies. Garcia *et al*. (2018), recorded the average longevity of the female 8.8 days, Saker *et al*. (2021) found that the longevity of the male and female was almost the same, as the male was 7.05 days and the female was 7.14 days, and Savadatti *et al*. (2023), recorded the shortest an average period of the male and female of *S. frugiperda,* as the male was 4.30 days, and the female was 5.30 days. The difference in results may be due to the use of a 10% sugar solution instead of a 5% honey solution, but this requires further study of the effect of different concentrations of sugar solution on the longevity of adults, the oviposition period, and pre-oviposition.

The results of the current study confirmed the existence of cannibalism within the larvae of the same age at all larval ages of *S. frugiperda*, but the rate of cannibalism was high in 4th and 5th larval ages compared to immature ages when reared on maize and castor plants, but the rate of cannibalism was in the total is high when reared on maize, and this may be due to the maize plant its preferred host. The results also show that the stage of larval development is an influential factor in cannibalism. The results of this study agree with Khafagi *et al*. (2023), who recorded the highest cannibalism rate in 4th larval age, 41.3% and the rate of cannibalism among larval instar was significant, and Tang *et al.* (2016) found that the cannibalism is more frequent by development larvae in 3rd, 4^{th,} and 5th with rate 41.6, 60, and 73.3, respectively. These results were contrary to the results by Murata *et al*. (2023), who found that cannibalism does not occur among 6th larval instar, although some larvae bite other individuals of the same age with their mandibles, Mbuji *et al*. (2022), recorded that cannibalism was not observed before 2nd larval age, and the highest rate of cannibalism was recorded in 5th larval age, while 6th larval age showed a decrease in activity and food intake, and this may be related to its entry into the pupation stage, Kasiga *et al*. (2022) found that the cannibalism did not occur in 1st and 2nd larval instars and recorded the highest rate of cannibalism in 4th and 5th with an average of 0.20 and 0.22, respectively, and decreased at 6th larval instar. Grobler (2019), who documented cannibalism in 4th larval age and above, it may be the possible reason for the absence of cannibalism in the first three instars that feed on maize may be the lack of pressure in terms of area and density and found the rate of cannibalism is higher when *S.frugiperda* larva reared on maize than castor, and Chapman *et al*. (1999b) observed that cannibalism is rare in the early stages of larval development and that it increases sharply in the 5th and 6th larval instars. The higher rate of cannibalism in *S. frugiperda* larvae that feed on maize than on castor may be due to the fact that castor leaves contain more nutritional value than maize leaves or may contain substances that alter the bacterial community within the digestive system of the larvae and thus could in turn affect their nutritional status larvae (Dyer *et al*., 2008; Da Silva & Parra, 2013; Maheshwari & Kovalchuk, 2016; Grobler, 2019). The higher incidence of cannibalism in mature larvae than in immature larvae is due to the increased mobility and higher predation force provided by the stronger physical structure of the mandible in the mature larvae (Zago-Braga & Zucoloto, 2004). Dial& Adler (1990) found that at the moment of molting, the larvae become more vulnerable to attack and cannibalism increases. A possible reason for the increase in cannibalism at older ages is that people eat more and become density population in terms of space (Fox, 1975; Polis, 1981; Joyner & Gould, 1985; Raffa, 1987; Richardson *et al*., 2010).The differences in the results of this study compared to previous studies may be due to the temperature, as Wang *et al*. (2010) found that temperature significantly affects the increase in cannibalism, and Tang *et al*. (2016) found that cannibalism behavior increases at 31°C compared to 22, 25, and 28°C.

Our study indicated that cannibalism is more frequent when the amount of food is 0.5 g/ 5 larvae compared to its occurrence when the amount of food is 2 g/ 5 larvae. The results of this study agree with Machado *et al*. (2022), who found that the absence of food led to an intensification of cannibalism in the fourth and fifth larval ages at a rate of 65 and 72%, respectively, at 31 °C, and that by increasing the amount of food, the rate of cannibalism decreased . they observed that the amount of 10g of feed artificial diet reduces cannibalism in the fifth larval instar, and the amount of 15 g of artificial diet is sufficient to feed larvae of the third and fourth instar for 72 hours, Ren *et al* . (2020) observed that cannibalism often occurs when rearing populations of FAW larvae, even though there is sufficient food available, Tang *et al*. (2016) found that cannibalism is influenced by the arrangement of food in the rearing container when using more complex combinations in artificial diet arrangements, which pose difficulties for the larvae to come into contact with each other, leading to lower rates of cannibalism, observed no significant differences in cannibalism between different treatments as the amount of food increased. Byrd & Castner (2001) reported that cannibalism in *S. frugiperda* larvae was common even when food was not limited but occurred increasingly at low food quantities or high rearing densities, and Fox (1975) mentioned that the relationship between the incidence of cannibalism and the amount of food is inverse and that cannibalism occurs even when its food sources are still plentiful. Chapman *et al*. (1999b) recorded that cannibalism in FAW larvae occurs until food is available. Cannibalistic behavior is affected by several factors, including temperature and quantity of food, the nutritional quality of the food, and the stage of the larvae (Sigsgaard *et al*., 2002; Richardson *et al*., 2010; Vangansbeke *et al*., 2014).

From the current study, it was recorded that cannibalism increases with a decrease in the space per larvae when kept in closed plastic boxes. Many studies agree with these results, as Grobler (2019) found that cannibalism was not significantly affected by differences in the density of larvae feeding on corn, and the rate of cannibalism increased with increasing density in a fixed area, Andow *et al*. (2015) reported that cannibalism is density dependent because as larvae congregate increasingly, encounters become more frequent and random. So, when there is a constant space for larvae, as density increases, the rate of cannibalism increases. Cannibalism in FAW larvae increases when food quantity is low and population density is high (Richardson *et al*., 2010; Vangansbeke *et al*., 2014; Murata *et al*., 2023).

5. Conclusion

The results of the current study indicated that cannibalism appears to be an obligatory behavior in fall armyworm larvae under laboratory conditions, and the frequency of cannibalism was higher when larvae were reared on corn leaves than on castor leaves. Cannibalism is affected by the type of food, quantity of food, larval density, and larval development. Cannibalism was frequently higher in fourth and fifth instar larvae, but there were no significant differences between cannibalism and larval development, density, and food quantity. Cannibalism increased at high density and low food quantity.

Acknowledgements

This study was kindly sponsored by the Plant Protection Department, Faculty of agriculture, South Valley University, Qena, Egypt.

Conflict of interest

The authors declare that there are no competing interests.

6. References

Ali, M. A., Abdellah, I. M., Eletmany, M. R. (2023). ‘Towards Sustainable Management of Insect Pests: Protecting Food Security through Ecological Intensification.’, *International Journal of Chemical and Biochemical Sciences,* 24(4), pp. 386-394.

Bentivenha, J. P., Baldin, E. L., Montezano, D. G., Hunt, T. E., Paula-Moraes, S. V. (2017). ‘Attack and defense movements involved in the interaction of *Spodoptera frugiperda* and *Helicoverpa zea* (Lepidoptera: Noctuidae).’, *Journal of Pest Science,* 90, pp. 433-445.

Bueno, R. C. O. D. F., Carneiro, T. R., Bueno, A. D. F., Pratissoli, D., Fernandes, O. A., Vieira, S. S. (2010). ‘Parasitism capacity of *Telenomus remus* Nixon (Hymenoptera: Scelionidae) on *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) eggs.’, *Brazilian Archives of Biology and Technology,* 53, pp. 133-139.

Byrd, J. H., Castner, J. L. (2001). ‘The utility of arthropods in legal investigations.’, *Forensic Entomology,* pp. 43-79.

Casmuz, A., Juárez, M. L., Socías, M. G., Murúa, M. G., Prieto, S., Medina, S., Gastaminza, G. (2010). ‘Revisión de los hospederos del gusano cogollero del maíz, *Spodoptera frugiperda* (Lepidoptera: Noctuidae).’, *Revista de la Sociedad Entomológica Argentina,* 69(3-4), pp. 209-231.

Chapman, J. W., Williams, T., Escribano, A., Caballero, P., Cave, R. D., Goulson, D. (1999a). ‘Fitness consequences of cannibalism in the fall armyworm, *Spodoptera frugiperda*.’, *Behavioral Ecology,* 10(3), pp. 298-303.

Chapman, J. W., Williams, T., Escribano, A., Caballero, P., Cave, R. D., Goulson, D. (1999b). ‘Age-related cannibalism and horizontal transmission of a nuclear polyhedrosis virus in larval *Spodoptera frugiperda*.’, *Ecological Entomology,* 24(3), pp. 268-275.

Chapman, J. W., Williams, T., Martínez, A. M., Cisneros, J., Caballero, P., Cave, R. D., Goulson, D. (2000). ‘Does cannibalism in *Spodoptera frugiperda* (Lepidoptera: Noctuidae) reduce the risk of predation?.’, *Behavioral Ecology and Sociobiology,* 48, pp. 321-327.

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

Cock, M. J., Beseh, P. K., Buddie, A. G., Cafá, G., Crozier, J. (2017). ‘Molecular methods to detect *Spodoptera frugiperda* in Ghana, and implications for monitoring the spread of invasive species in developing countries.', *Scientific reports,* 7(1), 4103.

D'amico, F., Vulcano, A., Murúa, M. G. (2021). 'Cannibalism and survival of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae under food scarcity.', *Annals of the Entomological Society of America*, 114(4), pp. 349-359.

Dahi, H. F., Salem, S. A., Gamil, W. E., Mohamed, H. O. (2020). 'Heat requirements for the fall armyworm *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) as a new invasive pest in Egypt. Egyptian Academic Journal of Biological Sciences.', *A, Entomology,* 13(4), pp. 73-85.

Day, R., Abrahams, P., Bateman, M., Beale, T., Clottey, V., Cock, M., … , Witt, A. (2017). 'Fall armyworm: impacts and implications for Africa.', *Outlooks on Pest Management,* 28(5), pp. 196-201.

Dial, C. I., Adler, P. H. (1990). 'Larval behavior and cannibalism in *Heliothis zea* (Lepidoptera: Noctuidae).', *Annals of the Entomological Society of America,* 83(2), pp. 258-263.

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

Dyer, J. M., Stymne, S., Green, A. G., Carlsson, A. S. (2008). 'High-value oils from plants.', *The Plant Journal*, 54(4), pp. 640-655.

Fernandez, F. J., Gamez, M., Garay, J., Cabello, T. (2020). 'Do development and diet determine the degree of cannibalism in insects? To eat or not to eat conspecifics.', *Insects,* 11(4), 242.

Fox, L. R. (1975). 'Cannibalism in natural populations.', *Annual review of ecology and systematics,* 6(1), pp. 87-106.

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

Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A., Tamò, M. (2016). 'First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (JE Smith) (Lepidoptera, Noctuidae)', *a new alien invasive pest in West and Central Africa. PloS one,* 11(10), e0165632.

Grobler, J. M. (2019). *'The effect of Ricinus communis on larval behavior and midgut microbe communities of Spodoptera frugiperda (Lepidoptera: Noctuidae)',* (Doctoral dissertation, North-West University (South Africa)).

He, L. M., Wang, T. L., Chen, Y. C., Ge, S. S., Wyckhuys, K. A., Wu, K. M. (2021). 'Larval diet affects the development and reproduction of the East Asian strain of the fall armyworm, *Spodoptera frugiperda*.', *Journal of Integrative Agriculture,* 20(3), pp. 736-744.

Hong, S., Titayavan, M., Intanon, S., Thepkusol, P. (2022). 'Biology and life table parameters of fall armyworm, *Spodoptera frugiperda* on three maize cultivars grown in Thailand.', *CMU J. Nat. Sci.,* 21(1), e2022001.

Joyner, K., Gould, F. (1985). 'Developmental consequences of cannibalism in *Heliothis zea* (Lepidoptera: Noctuidae).', *Annals of the Entomological Society of America,* 78(1), pp. 24-28.

Kasige, R.H., Dangalle, C., Pallewatta, N., Perera, M.T.M.D.R. (2022). 'Laboratory studies of larval cannibalism in same-age conspecifics of fall armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera, Noctuidea) in maize.', *Trop. Agric. Res. Ext.,* 25, pp. 85–92

Khafagi, W., Hegazi, E., Attia, M. A., Hasaneen, M. A. (2023). 'Cannibalism and necrophagy in *Spodoptera frugiperda* and *Spodoptera* *littoralis* (Lepidoptera: Noctuidae).', *Entomology and Nematology* 15(1), pp. 1-8.

Machado, L. C., dos Santos Junior, H. J. G., Paiva, C. E. C., dos Santos, B. A., Mauri, L. V. R., Rodrigues, J. A., ... , Zago, H. B. (2022). 'Canibalism in the larval instars of *Spodoptera frugiperda* (JE Smith, 1797) (Lepidoptera: Noctuidae): temperature and food quantity.', *Acta Scientiarum. Biological Sciences,* 44, e59401-e59401.

Maheshwari, P., Kovalchuk, I. (2016). 'Genetic transformation of crops for oil production.', *In Industrial oil crops (*pp. 379-412). AOCS Press.

Malekera, M. J., Acharya, R., Mostafiz, M. M., Hwang, H. S., Bhusal, N., 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.

Mbuji, A. L., Gong, X., Li, F., Yang, L., Shi, X., Peng, Z., ... , Wu, S. (2022). 'A study on the cannibalism behaviour and predation of the larvae of fall armyworm (*Spodoptera frugiperda*).', *Entomological Research*, 52(5), pp. 251-258.

Montezano, D. G., Sosa-Gómez, D. R., Specht, A., Roque-Specht, V. F., Sousa-Silva, J. C., Paula-Moraes, S. D., … , Hunt, T. E. (2018). 'Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas.', African entomology, 26(2), pp. 286-300.

Murata, M., Iida, H., Akiduki, G., Mitsunaga, T. (2023). 'An Efficient Rearing Method for the Fall Armyworm, *Spodoptera frugiperda*, under Crowded Conditions.', *Japan Agricultural Research Quarterly: JARQ*, 57(2), pp. 123-130.

Padhee, A. K., Prasanna, B. M. (2019). 'The emerging threat of Fall Armyworm in India.', *Indian Farming*, 69(1), pp. 51-54.

Polis, G. A. (1981). 'The evolution and dynamics of intraspecific predation.', *Annual Review of Ecology and Systematics,* 12(1), pp. 225-251.

Prasad, K. D., Prasad, B. S. R. V. (2018). 'Biological pest control using cannibalistic predators and with provision of additional food: a theoretical study.', *Theoretical Ecology,* 11(2), pp. 191-211.

Prowell, D. P., McMichael, M., Silvain, J. F. (2004). 'Multilocus genetic analysis of host use, introgression, and speciation in host strains of fall armyworm (Lepidoptera: Noctuidae).', *Annals of the Entomological Society of America,* 97(5), pp. 1034-1044.

Raffa, K. F. (1987). 'Effect of host plant on cannibalism rates by fall armyworm (Lepidoptera: Noctuidae) larvae.', *Environmental Entomology,* 16(3), pp. 672-675.

Ren, Q., Haseeb, M., Fan, J., Wu, P., Tian, T., Zhang, R. (2020). 'Functional response and intraspecific competition in the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae).', *Insects,* 11(11), 806.

Richardson, M. L., Mitchell, R. F., Reagel, P. F., Hanks, L. M. (2010). 'Causes and consequences of cannibalism in noncarnivorous insects.', *Annual review of entomology,* 55, pp. 39-53.

Sarkar, S., More, S. A., Tamboli, N. D., Kulkarni, S. R., Nimbalkar, C. A. (2021). 'Effect of temperature on the reproductive ability of Fall Armyworm- *Spodoptera frugiperda* (JE Smith) under laboratory condition.', *Journal of Pharmacognosy and Phytochemistry,* 10(6), pp. 154-158.

Savadatti, E., Ginnu, S. A., Mariyanna, L., Hosamani, A., Desai, B. R. K. R., Subbanna, A. D., Jalamangala, A. (2023). 'Temperature Effects on the Development of Life Stages of Fall Armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) on Maize.', *International Journal of*

Environment and Climate Change, 13(9), pp. 1884-1892.

Schlemmer, M. (2018). *'Effect of temperature on development and reproduction of Spodoptera frugiperda (Lepidoptera: Noctuidae)',* (Doctoral dissertation, North-West University).

Sigsgaard, L., Greenstone, M. H., Duffield, S. J. (2002). 'Egg cannibalism in *Helicoverpa armigera* on sorghum and pigeon pea.', *Bio. Control*, 47, pp. 151-165.

Silva, C. S. B. D., Parra, J. R. P. (2013). 'New method for rearing *Spodoptera frugiperda* in laboratory shows that larval cannibalism is not obligatory.', *Revista Brasileira de Entomologia*, 57, pp. 347-349.

Tang, T., Zhao, C., Xu, L., Qiu, L. (2016). 'Factors affecting larval cannibalism in the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae).', *Oriental insects*, 50(1), pp. 23-33.

Tian, T. A., Yu, L., Sun, G. J., Yu, X. F., Li, L., Wu, C. X., … , Liu, J. F. (2020). 'Biological control efficiency of an ectoparasitic mite *Pyemotes zhonghuajia* on oriental armyworm *Mythimna separata*.', *Systematic and Applied Acarology*, 25(9), pp. 1683-1692.

Vangansbeke, D., Nguyen, D. T., Audenaert, J., Verhoeven, R., Deforce, K., Gobin, B., … , De Clercq, P. (2014). 'Diet-dependent cannibalism in the omnivorous phytoseiid mite *Amblydromalus limonicus*.', *Biological Control*, 74, pp. 30-35

Wang, S., Tan, X. L., Zhang, F. (2010). 'Influence of kin relationship on cannibalism behavior of *Harmonia axyridis* (Coleoptera: Coccinellidae) fourth instar larvae in different temperature conditions.', *Acta Ecol. Sinica*, 30, pp. 5396-5403.

WU, L. H., Cao, Z. H. O. U., LONG, G. Y., YANG, X. B., WEI, Z. Y., Liao, Y. J., … , HU, C. X. (2021). 'Fitness of fall armyworm, *Spodoptera frugiperda* to three solanaceous vegetables.', *Journal of Integrative Agriculture*, 20(3), pp. 755-763.

Zago-Braga, R. C., Zucoloto, F. S. (2004). 'Cannibalism studies on eggs and newly hatched caterpillars in a wild population of *Ascia monuste* (Godart) (Lepidoptera, Pieridae).*', Revista Brasileira de Entomologia*, 48, pp. 415-420.