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BIOLOGY AND GROWTH INDEX OF FALL ARMY ARMYWORM, *Spodoptera frugiperda* (LEPIDOPTERA: NOCTUIDAE) REARED ON DIFFERENT HOST PLANTS

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The fall armyworm (FAW) *Spodoptera frugiperda* (J. E. Smith) is a polyphagous pest that can attack numerous hosts and causes high damage. The present work was conducted at Bollworms Research Department under laboratory condition of (26 ± 2 °C, 70 ± 5 % RH) to study the possibility of rearing FAW on three different hosts, [*Pisum Sativum* (Pea), *Lactuca sativa* (Lettuce) and *Ricinus communis* (Castor)] and evaluate its biological parameters and growth index. Obtained results revealed that Pea was the best in rearing FAW causing the lowest larval mortality (13.33%) and the fastest developmental time (30.33 days/total immature), followed by Lettuce (14.93% larval mortality and 32.37 days/total immature), compared to castor that produced the highest larval mortality percent (16.67%) with the slowest duration (33.29 days). In addition, rearing FAW produced a higher fecundity (880.67eggs/female) which decreased significantly (663.38 and 616 eggs/female) for Lettuce and castor, respectively. The growth and fitness index were highest on pea recorded 4.41 and 0.55 respectively, followed by Lettuce (3.98 and 0.47) while they were 3.74 and 0.42) for Castor host, respectively. Thus, Pea appears to be the most favorable host plant in rearing *S. frugiperda* compared to the other two hosts.

Keywords: Biology; fall armyworm; growth index; pea; castor.

1. INTRODUCTION

Fall armyworm (FAW), *Spodoptera frugiperda* (J E Smith) (Lepidoptera: *Noctuidae*) is one of the most destructive worldwide polyphagous pest that has a wide range of host plants. It has been detected in several countries such as Brazil, Argentina, and the USA [1,2]. According to the Food and Agriculture Organization of the United Nations (FAO), the pest has been reported in Egypt in 2019 [3]. *S. frugiperda* is considered to be the most serious lepidopterous pest as it causes economic losses in many crops such as maize, soybean, and beans [4,5], several weeds, such as Ipomoea sp., and other grasses such as Bermuda and cowpeas [6], added to high yield lost in other cultivar plants [7,8,9]. FAW larvae prefer to feed on foliage and tissue destroying the plant budding point. The first larval instars cause damage by consuming

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foliage tissue from one side, leaving the membranous epidermal layer on the other side. Older instars begin to make holes in leaves starting from the edge inward. The oldest larvae cause much more extensive damage causing defoliation or a ragged, torn appearance [10]. The forewings of male moth are generally shaded gray and brown, with triangular white spots at the tip at the end of the wing while, The female forewings are less distinctly marked, grayish-brown in color with white hind wings in both sexes [11,12]. Generation time takes about (4–13) weeks depending upon the availability of a preferable host and developmental conditions [13]. Limited studies have been conducted on *S. frugiperda* biology and life cycle as it is a new invasive pest in Egypt. Consequently, this research will be instrumental in describing the developmental parameters of *S. frugiperda* on various host plants under laboratory conditions that could be used as a potential for mass rearing as a prerequisite for effective integrated pest management strategies.

2. MATERIALS AND METHODS

2.1 Collection and Mass Rearing of *S. frugiperda*:

A stock colony of *S. frugiperda* larvae was originally collected from maize fields at El-Fayoum governorate, Egypt, during the winter (November and December 2021) without any insecticide contamination. The larvae were reared individually on Pea, Lettuce and Castor host plants for one generation. The colony was maintained under laboratory-controlled conditions (26 ± 2 °C, 70 ± 5 % RH) in an electrical incubator. Three colonies were fed on three tested host plants: (Pea =A), (Castor = B), and (Lettuce = C). Larvae of each colony were inspected daily (with food replacement two days intervals) till pupation. The pupae thus formed were collected and placed in a glass jar (with tissue paper at its bottom) till adult emergence. The mouth of the jar was covered with muslin cloth and tied with rubber band The emerged adults for each colony were placed in rearing cages (1L) (Three pairs/cage), covered from both sides with muslin cloth. Another piece of muslin cloth was hung inside the cage for Oviposition. Cotton balls with 10% sucrose solution were suspended inside the cage for the adult moth's nutrition. Deposited eggs were collected daily. Hatched neonates were reared following the same procedure and were used for further studying the biological parameters of FAW on tested host plants.

2.2 Host Plant

Larvae of S. *frugiperda* were fed on three host plants:

- Pea, (*Pisum Sativum*).
- Lettuce leaves, (*Lactuca sativa*).
- Castor leaves, (*Ricinus. communis*).

2.3 Evaluation of Biological Parameters of FAW on Three Different Hosts

The newly hatched larvae of *S. frugiperda* for each colony (A, B, and C) of the rearing host plant were transferred individually to a glass tube (3×7.5cm) containing the same host plant. For each host plant (Pea, Castor, and Lettuce), Three replicates (30 larvae/replicate) were prepared. Observations were taken daily on the number of dead larvae and pupae, their weights, and durations till adult emergence. The emerged adults for each host plant were sexed (3♂ X 3♀) and caged for eggs laying (5 replicates/treatment). All cages were examined daily to determine the pre-oviposition, oviposition, post-oviposition periods and adult longevities. Eggs were collected and counted daily and then kept at the previous rearing conditions till hatching. The mean number of deposited eggs (fecundity) was recorded. The hatchability and sterility percentage were calculated according to Zidan and Abdel-Megeed [14]. Also, the growth and fitness index of different FAW stages were calculated according to Pretorius, [15] and Itoyama et al., [16].

Calculations:

$$\textbf{\% Larval mortality} = \frac{\textbf{No.of Dead larvae}}{\textbf{Total Noof.Larvae}} \textbf{x100.}$$

$$\textbf{\% Pupation} = \frac{\textbf{No.of Produced pupal}}{\textbf{Total No.of Larvae}} \textbf{x100.}$$

$$\textbf{\% Pupal mortality} = \frac{\textbf{No.of Dead Pupae}}{\textbf{Total No.of Pupae}} \textbf{x100.}$$

$$\textbf{\% Adult emergence} = \frac{\textbf{No.of Emerged moth}}{\textbf{Total No.Pupae}} \textbf{x100.}$$

$$\textbf{\% Hatchability} = \frac{\textbf{No.of Hatched eggs]}}{\textbf{No.of Total eggs}} \textbf{x100.}$$

$$\textbf{\% Female (♀) ratio} = \frac{\textbf{No. of female moths}}{\textbf{Total No.of moths}} \textbf{x100}$$

$$\textbf{Larval growth index} = \frac{\textbf{Pupation (\%)}}{\textbf{Larval period (days)}}$$

$$\textbf{Pupal growth index} = \frac{\textbf{Emergence(\%)}}{\textbf{Pupal period (days)}}$$

$$\textbf{Immature growth index} = \frac{\textbf{Emergence}(\%)}{\textbf{Total immature duration (larval period+pupal period)}}$$

$$\textbf{Standardize growth index} = \frac{\textbf{Pupal weight}(\textbf{g})}{\textbf{Larval period (days)}}$$

$$\textbf{Fitness index} = \frac{[\textbf{Pupation}\ (\%) \times \textbf{Pupal weight}(\textbf{g})]}{\textbf{Total immature duration (days)}}$$

Statistical Analysis: The obtained data were statistically analyzed with one-way analysis of variance (ANOVA) (P =.05) according to Snedecor, [17] and Duncan's multiple range test of means [18].

3. RESULTS

3.1 Effect of Different Host Plants on *S. frugiperda* Immature Stages

Data in Table 1 shows the percent of larval mortality by feeding the newly hatched larvae of *S. frugiperda* on pea, castor, and Lettuce plants. The Pea appears to be the most favorable host for *S. frugiperda* larvae as it recorded the lowest mortality percentages (13.33%) which increased significantly to 16.67% in Castor and insignificantly to 14.93% in Lettuce. The mean larval period for FAW was also affected by host type. The shortest period was recorded on pea (19.67 days) followed by 21.4 and 22.27 days in Lettuce and castor, respectively with no significant difference among the three hosts. The average weight of *S. frugiperda* larvae reared on Pea host was the heaviest as it recorded (0.291g) compared to (0.251and 0.238 g) in Lettuce and Castor, respectively (Table 1). The highest percent of pupation (86.67%) was observed in pea with the lowest pupal mortality (6.4%) followed by Lettuce (85.07 and 10%) while decreased significantly to (83.33 and 12%) for Castor, respectively. The effect on the pupal weights was also detected as they recorded (0.193 and 0.179g) for pea, Lettuce respectively, and decreased significantly to (0.167g) for castor. Additionally, the pupal duration was reported (10.67, 10.97, and 11.02 days) and subsequently the total immature duration (30.33, 32.37 and 33.29 days) for pea, Lettuce, and castor plants respectively with no significant difference among the three hosts (Table 1).

3.2 Effect on *S. frugiperda* Adult Emergence and Reproductive Parameters

The impact of rearing FAW neonates on different host plants subsequently affects the emerged adults (Table 2). The percent of adult emergence reached 93.6% for Pea which reduced significantly to 90 and 88 % for Lettuce and Castor, respectively. The sex ratio of emerged moths was shifted to the female side for all host plants. The prominent female sex ratio (63.33, 56.67 and 51.67 % for Pea, Lettuce, and castor respectively), was approved by the high fecundity. The mean number of deposited eggs of female moths reared as neonate on the pea host plant was 880.67 eggs, this number was significantly reduced to 663.38 and 616 eggs) for Lettuce and castor respectively. Also, the mean hatchability percentage was (93.2%) for Pea and insignificantly reduced to 90.9and 89.33% for Lettuce and castor respectively. Accordingly, a subsequent reflection was reported on the observed sterility percentages (6.8, 9.1, and 10.67%) for Pea, Lettuce, and castor respectively, (Table 2).

3.3 Effect on Adult Longevity of *S. frugiperda*

Data in Table 3 showed that the adult longevity of *S. frugiperda* was influenced by host plant type. However, no significant difference was found in both male and female adult longevity across hosts. The shortest mean values of adult male longevity were 9.9 days on Lettuce, followed by castor (10.1 days) and Pea (10.67 days). A reversed action was reported for female longevity where the shortest females' longevity was 11.67 days on Pea followed by Lettuce (11.83 days) and Castor (12.08 days). Moreover, the total Oviposition periods of *S. frugiperda* produced no significant differences between the three different host plants. For both pre-and post- Oviposition periods Castor was the longest (4.25 and 3.5 days respectively), followed by Lettuce and Pea. This was reversed for the Oviposition period that recorded the longest value on Pea host plant (5 days) followed by Lettuce and Castor (4.83 and 4.33 days) respectively, (Table 3). Accordingly, Figs. 1, 2 and 3 showed all developmental stages of *S. frugiperda* reared as neonates on pea Lettuce and Castor hosts, respectively. Moreover, the type of host affecting the color of deposited eggs as well as produced larvae that was clearly appeared in the noticeable green color of eggs and larvae of pea host (Fig.1) compared to Lettuce and Castor hosts (Figs. 2 and 3).

3.4 Growth and Fitness Indexes

The relation between the survival rate and developmental time depending on the food quality of the host pant can be expressed in the growth index. Data in Table 4 shows that the highest larval growth index of FAW was on Pea (4.41) while the lowest was

Table 1. Effect of host plants on developmental parameters of *S. frugiperda* immature stages

Host plant	Larval stage			Pupal stage				Total immature duration (days) (M±SE)
	% Larval mortality	larval period (days) (M±SE)	Larval weight (g) (M±SE)	% Pupation	% Pupal mortality	Pupal period (days) (M±SE)	Pupal weight (g) (M±SE)	
pea	13.33[b]	19.67[a]±0.88	0.291[a]±0.0020	86.67[a]	6.4[b]	10.67[a]±0.66	0.193[a]±0.0033	30.33[a]± 1.43
Lettuce	14.93[ab]	21.4[a]± 1.40	0.251[a]±0.0253	85.07[ab]	10[a]	10.97[a]±0.48	0.179[ab]±0.011	32.37[a]± 0.32
castor	16.67[a]	22.27[a]±0.37	0.238[a]±0.0297	83.33[b]	12[a]	11.02[a]±0.56	0.167[b]±0.0036	33.29[a]± 0.20
LSD 0.05	2.0211	3.4173	0.0780	2.0211	2.0922	1.9905	0.0242	3.7172

Notes *Means within a column followed by the same letters are not significantly different*
M: mean, g: gram. SE: standard error

Table 2. Effect of host plants on developmental parameters of *S. frugiperda* emerged adults

Host plant	Adult stage				
	% Adult emergence	% Female(♀) ratio	Fecundity (M±SE)	% Hatchability	% Observed Sterility
pea	93.6[a]	63.33[a]	880.67[a]±4.177	93.2[a]	6.8[a]
Lettuce	90[b]	56.67[a]	663.38[b]±15.610	90.9[a]	9.1[a]
Castor	88[b]	51.67[a]	616[b]±26.47	89.33[a]	10.67[a]
LSD 0.05	2.0922	15.8157	117.35	3.9068	4.9068

Table 3. Effect of host plants on adult longevities of *S. frugiperda*

Host plant	Adult stage				
	Pre-Oviposition (days) (M±SE)	Oviposition (days) (M±SE)	Post Oviposition (days) (M±SE)	♀ Longevity (days) (M±SE)	♂ Longevity (days) (M±SE)
pea	3.83[a]± 0.133	5.0[a]± 0.289	2.83[a]± 0.167	11.67[a]± 0.167	10.67[a]± 0.333
Lettuce	3.83[a]± 0.167	4.83[a]± 0.167	3.17[a]± 0.167	11.83[a]± 0.167	9.9[a]±0.10
Castor	4.25[a]± 0.382	4.33[a]± 0.333	3.5[a]± 0.289	12.08[a]± 0.464	10.1[a]± 0.586
LSD 0.05	0.8441	0.94182	0.7446	1.0397	1.3616

Notes *Means within a column followed by the same letters are not significantly different.*
M: mean. SE: standard error

Table 4. Growth indexes and fitness index of *S. frugiperda* on three natural host plants

Host plant	Larval growth index	Pupal growth index	Immature growth index	Standardized growth index	*Fitness growth index*
pea	4.41	6.7	3.1	0.0098	*0.55*
Lettuce	3.98	8.2	2.8	0.0084	*0.47*
castor	*3.74*	*7.99*	*2.6*	*0.0075*	*0.42*

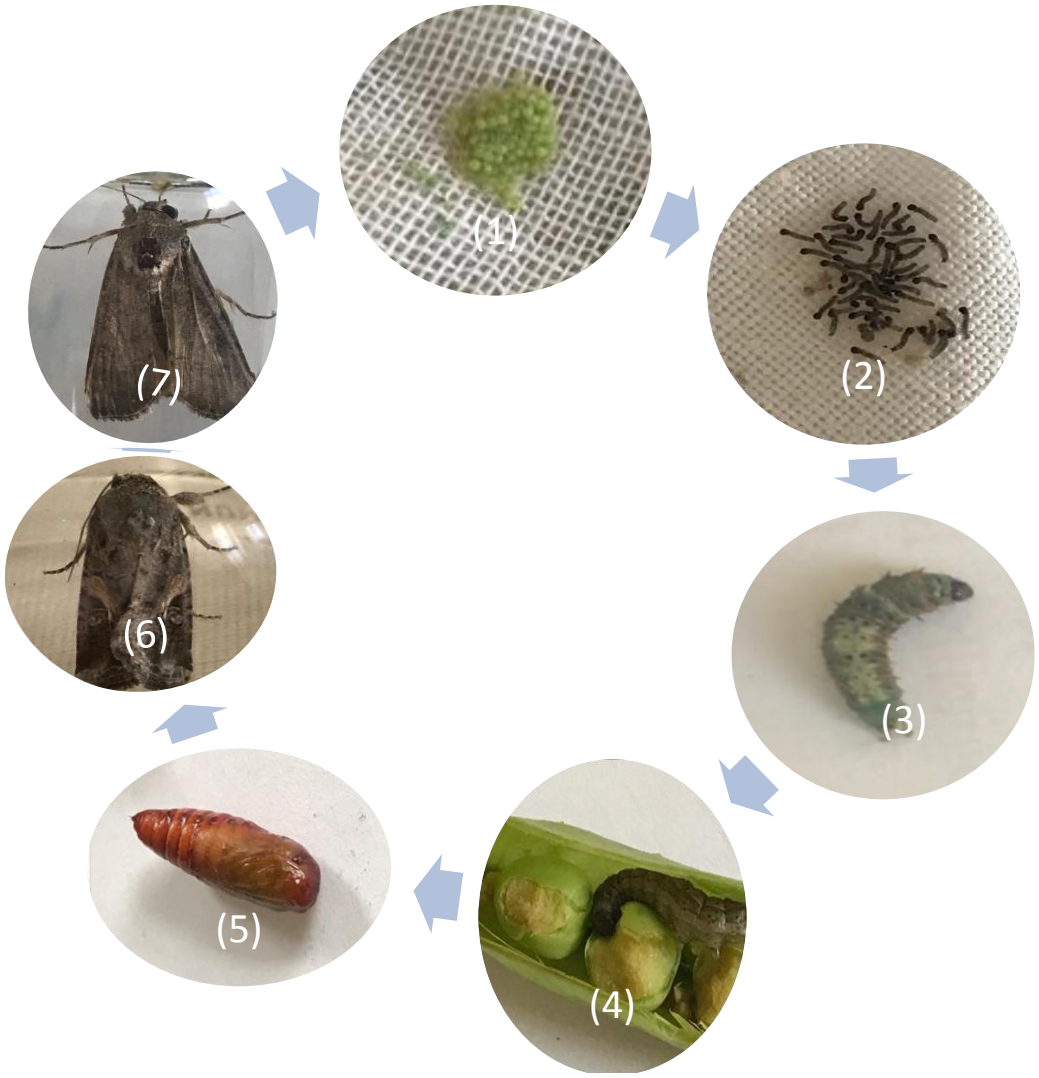

Fig. 1. *S. frugiperda* Life cycle on Pea host plant showing its different developmental stages

on Castor (3.74). However, the pupal growth index was lowest on Pea (6.7) followed by Castor (7.99) and Lettuce (8.2). The highest growth index of immature stages was 3.1on pea while the lowest was 2.6 on Castor with a mid-growth index for Lettuce (2.8). Table 4 also, indicates that the standardized growth index of 0.0098 on Pea followed by 0.0084 on Lettuce, and 0.0075 on Castor. In addition, the highest fitness index was 0.55 on Pea followed by 0.47 and 0.42 on Lettuce and Castor, respectively.

4. DISCUSSION

Feeding the newly hatched larvae of *S. frugiperda* on different host plants affects their growth and development. Pea Lettuce and Castor leaves have been used for rearing *Helicoverpa armiger* and *Spodoptera litura* and were also suitable for *S. frugiperda* in our study. Pea host plant recorded the lowest larval mortality percentages with a faster development time and higher growth rate thus it appears to be the most favorable host plant compared

with the other two hosts. However, the high survival rates of FAW on pea indicate that its nutritional contents are suitable for insect growth and development. Likewise, many studies have shown that the type of food consumed by insects affects their host preferences and has an impact on their biology. Hwang et al., [19] indicated that feeding lepidopterous larvae with high nutritious food increase growth rates and complete developmental time faster than larvae that are fed on low nutrient food. According to Shekhawat et al, [20], variances in the FAW larval duration could be related to differences in nutrition in the feed given, this was explained by Roeder et al, [21] who stated that Insects fed on hosts of low nutritional value can resort to extend its duration. Moreover, feeding neonates of *S. frugiperda* on Pea host produced the heaviest average weight value of larvae and pupae with a significant percent of pupation and adult emergence followed by Lettuce and Castor plants. These results are in accordance with the research of (Montezano et al., [22] and Subiono, [23] who reported that the type of food affects insect weight and development cycle from early to late stages. Putra and Khotimah [24] stated an increase in larval weight in feeding *S. frugiperda* on the preferred food compared to unfavorable one. Similar to earlier findings reported that the average larval duration of *S. frugiperda* was 23.36and 22.8 days, in addition to pupation % of 95, and 88.8 % after larval feeding on castor leaves and lettuce, respectively [25]. Furthermore, Sex ratio is an important factor to be studied as it affects the Probability of mating. According to our results, the sex ratio of *S. frugiperda* emerged moths was shifted to the female side reflecting the high fecundity produced. The higher the female ratio in the population, the higher probability of mating [26,27], and so the higher the number of eggs produced in the next generation, [24]. Accordingly, the developmental and reproductive variation that could be detected among the three host plants is due to the food type. Whereas, each food type has different nutritional content that is needed by adult insects to increase fecundity, and fertility, and balance the sex ratio [28,29,30]. Similar findings of low fecundity were reported on feeding *Spilosoma oblique* [31], and *Macrosiphum rosae* [32] larvae on poor nutritional host plants.

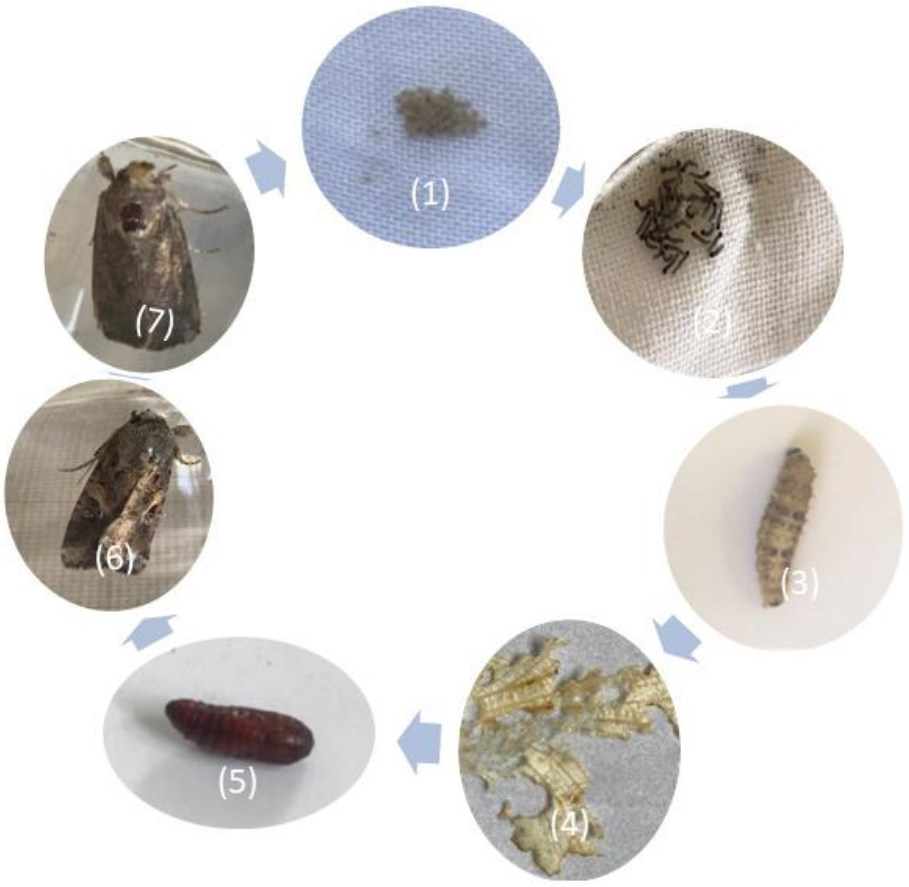

Fig. 2. *S. frugiperda* Life cycle on Lettuce host plant showing its different developmental stages

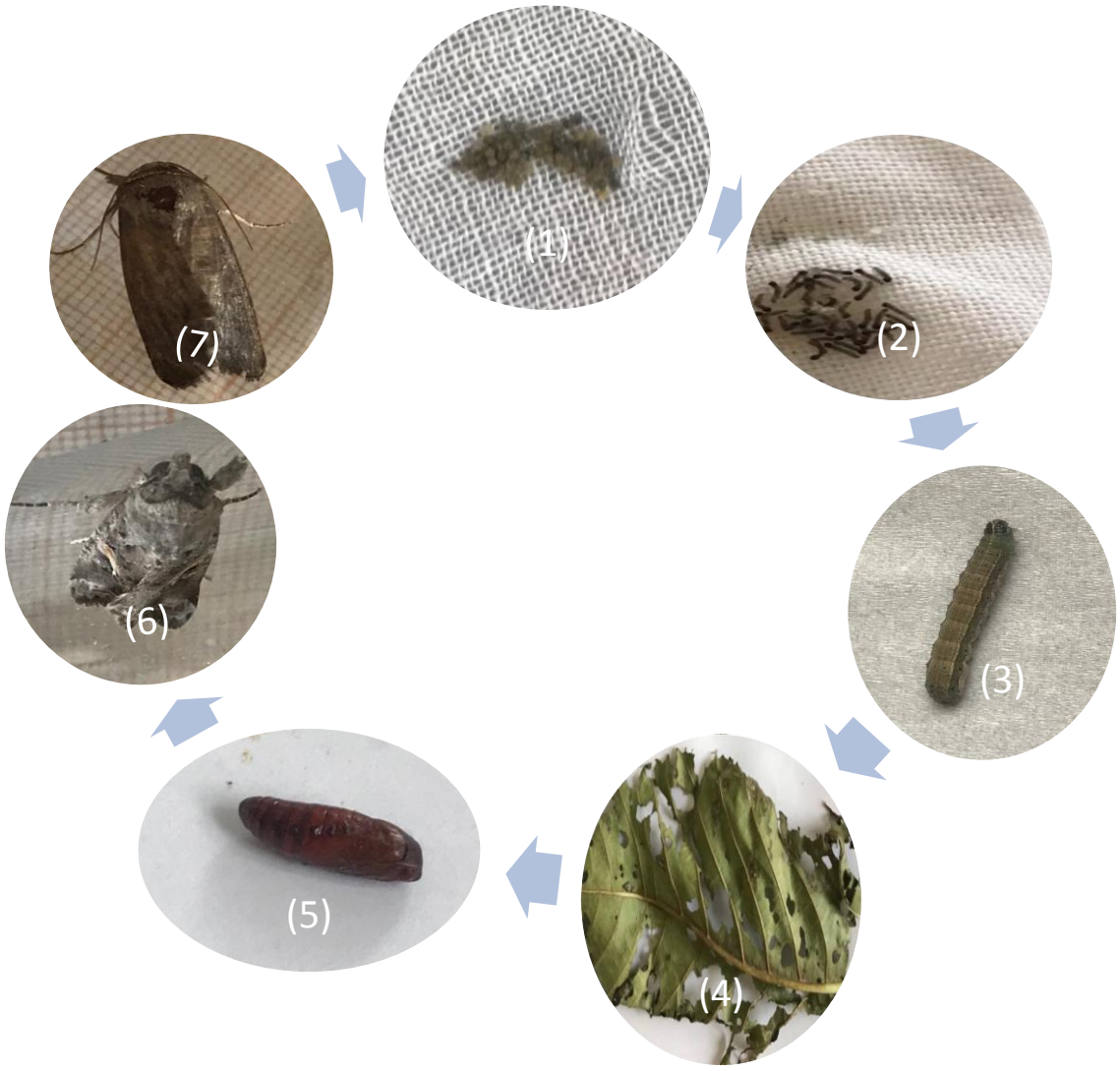

Fig. 3 *S. frugiperda* Life cycle on Castor host plant showing its different developmental stages

1. **Eggs**
2. **Neonates**
3. **Large larva**
4. **Feeding effect on host plant**
5. **Pupa**
6. **Adult male**
7. **Adult female**

The growth index defines the importance of the host plant in determining developmental and fitness costs in insects [33]. The highest growth and fitness index values for FAW wand were on Pea, and the lowest growth and fitness index values for FAW were on the castor host plant. Similar to our results, Amer and El-Sayed [34], reported that the highest growth and fitness index for *Helicoverpa armigera* were on pea compared to different other host plants.

5. CONCLUSION

The results of this study pointed out the variable impact of host plant type on the biological parameters of the FAW with the preference of pea more than the two other host plants. Thus, it could be used economically for mass rearing for many generations as a prerequisite for effective integrated pest management strategies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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