

## Biology and Feeding Preferences of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) On Maize And Selected Vegetable Crops

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### ABSTRACT

**Purpose :** Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae) was recently reported for the first time in Sri Lanka in Oct 2018 as a new invasive pest of maize. Therefore, the objectives of present study were to study biology and to evaluate feeding preferences of *S. frugiperda* on maize and selected vegetable crops.

**Research Method :** During the experiment, newly hatched larvae were fed with maize, cabbage, okra, beans, radish and brinjal leaves under laboratory conditions. Maize was used as the positive control. Duration of development from larva to adult, pupal weight, pupal length, sex ratio, survival percentage, and oviposition (Choice and No-Choice test) on different vegetable crops were evaluated.

**Findings :** Results of the feeding preference test envisaged that there was no host dependent variability among neonate larvae for maize, cabbage, raddish and brinjal. The highest damage (50-75%) was reported in larvae fed on okra, and (25-50%) damage was showed in beans after 24 hours of inoculation. The highest survival percentage of larvae (80%) and shortest larval development period (23.8±0.3days) were reported in larvae fed with maize where as it was the longest in brinjal. The highest oviposition (4.1±1.2 in Choice test and 3.6±0.7 in No-choice test) was observed in maize compared to other crops. With the absence of the most preferred host (maize) for oviposition, other hosts were used by the pest. During the off season Fall armyworm could survive in alternate crops.

**Research Limitations :** Field observations were not carried out to confirm (validate) the laboratory observations with the time limitation.

**Originality/ Value :** The research provides interest and idea about the survival mechanism of *S. frugiperda* during off season of maize and potential alternative host plants of the pest. It identifies the possibility of moving of *S. frugiperda* into five vegetable crops and thereby make awareness of the farmers about the pest to follow the suitable management practice of the *S. frugiperda*.

**Keywords:** Alternative host plant, Emergence, Oviposition, Sex ratio, Survival

### INTRODUCTION

The Fall Armyworm (FAW) *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), has been (recorded as a) identified as a sporadic, polyphagous and migratory pest species in the world (Hardke *et al.*, 2015). Food and Agriculture Organization of the United Nations reported that *S. frugiperda* is native to tropical and sub-tropical regions of America and was first reported in Africa in 2016. All around the world,

maize crop was damaged by *S. frugiperda* larvae. Moreover, high reproductive rate of the pest and occurrence of several generations per single year lead to high crop damage.

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In Sri Lanka, the pest infestation was first reported at Damana region in Ampara district (Perera *et al.*, 2019). Later, it was reported in Anuradhapura, Monaragala, Kurunegala, Kandy, Badulla and Ratnapura districts and almost 50% of Sri Lankas' maize cultivations were infested by *S. frugiperda* during 2018/19 Maha season. Almost all growth stages of the Maize crop can be seriously infested by the pest and the latter stage larva consumes high compared to initial stages (Perera *et al.*, 2019).

The pest undergoes a complete metamorphosis and the pest biology is greatly influenced by the tropical climatic conditions and available host plants. Accurate identification of pest life cycle, growth characteristics, feeding preferences and host preferences for oviposition are important to understand the biology of the pest and pest biology is very important in planning effective pest control. Host preference of the pest could be varied with larval instar (age) and their survival might be different with the type of host plants (Perera *et al.*, 2019, Rojas *et al.*, 2018). Moreover, biological variables such as duration of larval period, pre-pupae (non-feeding stage between the active larva and pupa), pupae and total period from larva hatching to adult emergence (days), pupae weight and length, sex ratio, and survival percentage can be varied with the different host plants (Silva *et al.*, 2017). Even though, biology and feeding preferences of *S. frugiperda* were reported from African, American and other regions of the world, limited information were reported under local conditions where behaviors could be completely different. Addition to damage on maize, the pest could be infested to other field crops (cereals, fruit and vegetable crops) under local environment conditions. Studies showed that performances of FAW in different host plants vary including their longevity, survival and oviposition (Fei, Guo *et al.*, 2020). Detailed investigation of FAW's performances on different alternative host plants serves the best to predict types of other host plants in a threat with the absence of preferred host. Therefore, the main objective of present study was to identify the biology and feeding preferences of *S. frugiperda* on selected vegetable crops under laboratory conditions.

## MATERIALS AND METHODS

### *Host Plants and Crop Establishment*

The experiment was conducted as a pot-trial at Horticultural Crop Research and Development Institute, Sri Lanka (HORDI). Accordingly, five vegetable crops namely, cabbage (*Brassica oleracea*) Exotic fl variety, okra (*Hibiscus esculentus*) variety MI5, beans (*Phaseolus vulgaris*) variety Gannoruwa green, radish (*Raphanus sativus*) variety Beeralu, brinjal (*Solanum melongina*) variety Lenairi and one cereal maize (*Zea maize*) variety Pacific were used as host plants and maize was considered as reference host. Potting media was prepared, using sand: top soil: compost at 1:1:1: ratio. Seeds of selected crop were sown in nurseries and two weeks old seedlings were transplanted to pots. Plant nutrition management was done as per the Department of Agriculture (Sri Lanka) recommendations (Anonymous, 1992). Crops were managed without applying any pesticides and allowed growing until 8-10 leaf stage before introducing *S. frugiperda* neonate larvae.

### *S. frugiperda* Culture Preparation

Egg masses were collected from *S. frugiperda* rearing unit at Horticultural crop Research and Development Institute and kept inside plastic cups with proper ventilation. To keep the freshness, a wet tissue paper was kept inside the plastic cup before introduction of leaf with egg masses. On an average 2-3 days were taken to hatch above egg mass. Larvae that just after hatched were separated and were used to inoculate host plants. Larvae were fed daily with fresh maize leaves and clean culture environment was maintained inside to avoid contaminations. Pupae were separated into separate cup and kept inside cages until the emergence of moths. Cotton soaked sugar solution and water were supplied for moths.

### *Lifecycle of S. frugiperda on different host plants*

Leaf samples from six selected crops were placed in six different plastic containers and ten

neonate larvae were introduced to each. The experiment was replicated three times. Larvae were kept inside the plastic cups (10 cm diameter and 7cm height) until they complete the lifecycle (i.e. emergence of the moths) and number of days taken to complete each stage of life cycle was recorded. By assuring adequate food supply, all larvae were fed daily with specific fresh leaf samples. Larvae were fed using same leaf areas of each selected crops. These larvae were observed daily to assess their life cycle variables such as duration of larvae to pupation, pupae to emergence of adult, total days to complete the life cycle, male and female pupae weight (g) (measured at 24 hours after pupation), number of females to male sex ratio, and survival percentage (number of larvae complete the lifecycle).

### ***Host-plant preference for oviposition***

Host preference of females for oviposition was studied under laboratory conditions. This experiment was done by two methods as Choice test and No-Choice test. Selected plants (cabbage, okra, beans, radish, brinjal and maize) at similar growth stages (plants having 8 to 10 fully expanded leaves) were placed inside screen cages and female and male moths (4-5 days old) were introduced to each cage at 1:1 ratio (6 female and 6 male moths per cage). The experiment was replicated six times and sugar solution and water were supplied to feed the moths.

In Choice test all tested vegetable crops were randomly placed inside the cages (4ft×1.5ft×2.5ft) and moths (6 female and 6 male moths per cage) were released allowing them to select most preferable host plant for oviposition. This was replicated six times. In No-Choice test out of six plants one host was kept inside the cage at a time (46cm×41cm×43cm) and moths (1 female and 1 male per cage) were introduced. This was replicated six times. After five days, egg masses were collected from both Choice and No-Choice tests and were used to estimate number of egg masses in each treatment, number of eggs per egg mass and length of the egg mass (cm).

### ***Feeding preference of neonate larvae to selected crops***

This was designed to evaluate the feeding preference of the pest under laboratory condition. Similar size (2cm x 4cm) leaf samples (same maturity) from each host were kept randomly inside the plastic container (24cm×12cm×7cm). To keep the freshness, wetted tissue papers were laid on the bottom of plastic container and 20 neonate larvae were introduced into middle of the container. This experiment was replicated for ten times and damage was recorded as described in Ayala *et al.* (2013).

#### **Damage scale**

- 1- No damage
- 2- <25%
- 3- 25% - 50%
- 4- 50% - 75%
- 5- 75% - 100%

Moreover, feeding preference of each host was recorded at 1 h, 3 h, and 24 h and 48 h time intervals, by visual observation according to the above scale.

### ***Statistical Analysis***

Data was statistically analyzed using Statistical Analysis Software (SAS) packages. Parametric Data were analyzed using Analysis of Variance (ANOVA) and mean separation was done by using Duncan Multiple Range Test (DMRT) at 5% interval. Categorical data analysis procedures were used to analyze non parametric data and significance of the treatment effects was obtained at  $p < 0.05$  level. The Microsoft Excel (2010) computer software Package was used to prepare graphs.

## RESULTS AND DISCUSSION

### *Lifecycle of S. frugiperda on different host plants*

Tested crops had a significant effect ( $p < 0.0001$ ) on life cycle length of *S. frugiperda*. The Larvae that fed on maize complete their larvae period in  $16.0 \pm 0.2$  days and that was the shortest among the tested crops. Larval period on cabbage ( $21.4 \pm 0.3$  days) was shorter than that of okra ( $23.5 \pm 1.0$  days), beans ( $23.5 \pm 0.0$  days) and brinjal ( $23.6 \pm 0.8$  days). However, larval period of cabbage was not significantly different from the radish ( $23.0 \pm 0.5$  days).

Pupae period was significantly shorter in beans ( $7.2 \pm 0.5$  days), brinjal ( $7.3 \pm 0.5$  days) and okra ( $7.2 \pm 0.5$  days) compared to cabbage ( $9.1 \pm 0.3$  days) and radish ( $9.4 \pm 0.3$  days). However, none of the above were different from maize ( $7.9 \pm 0.2$  days) pupae period. Considering both larvae and pupae period together (larvae to adult period) larvae feed on maize ( $23.8 \pm 0.3$  days) took the shortest time to emerge adult and that was significantly different from all other host plants.

Type of host plants is significantly affected ( $p < 0.0004$ ) on pupae growth in term of their length and weight (Table 01). Accordingly, the highest pupae length ( $1.7 \pm 0.02$ ) was observed in maize and that was the lowest in okra and beans ( $1.4 \pm 0.05$  and  $1.3 \pm 0.04$ ). Significantly greater male and female pupae weights were observed in maize in comparison to all other crops (Table 01). Weight of male pupae was not significantly different between cabbage, okra, beans, radish and brinjal. However, that for female was the lowest in vegetables than maize.

Male larvae survival percentage (number of larvae complete their lifecycle of *S. frugiperda*) was the highest in radish (36%) and in maize it was 33%. That was the lowest in Okra (0%), Beans (6%) brinjal (3%). Significantly greater female larvae survival percentages were observed in maize (46%), in comparison to okra (13%), beans (6%) and brinjal (6%). However, that was not different from cabbage (23%) and radish (16%). In general, selected crops were female biased in survival. However, radish was male biased where, survival of male larvae (36%) was

compared to female (16%). Sex identification of larvae was based on the visual observations after moth emergence.

Among the tested crops, the shortest life cycle of *S. frugiperda* was observed in maize. A similar result was reported by Meagher *et al.* (2004) compared to cowpea and sunnhemp. Moreover, maize showed a positive effect on larval growth, (i.e. greater pupal weights and pupal lengths) and development (short time taken by larvae to pupate and pupate to emergence of adults) compared to tested five vegetables (cabbage, okra, beans, radish and brinjal). Together with those factors, greater survival rates indicate the *S. frugiperda* preference on maize. Therefore, present study revealed that tested five vegetables were less preferred by *S. frugiperda* compared to the maize. This could be attributed to the quality of food; Barros *et al.* (2010), reported development of insects depends on the quality of the food. Similar results revealed that, this insect preference and best performance for grasses have been previously demonstrated by other researchers. In Buntin, (1986), Lewter *et al.* (2006) and Nagoshi *et al.* (2004) have shown that *S. frugiperda* preferred grasses such as maize, sorghum, and bermuda grass, which are C4 plants than C3 plants. And Silva *et al.* (2017) has identified grass species evaluated in his study were the most suitable host for the growth of *S. frugiperda*. At the same time, other researchers found that biochemical substances produced by plants under pest attack according to Hoffmann Campo *et al.* (2001) and Piubelli *et al.* (2005) influence the growth, survival, and reproduction of insects (Fischer *et al.*, 1990).

Lower survival percentage of larvae was observed in brinjal, okra and beans, which were not significantly different, compared to maize, cabbage and radish. Lesser survival of larvae in above mentioned crops was difficult to justify due to reported greater natural mortality in the early larval stages of Lepidopteran (Zalucki *et al.*, 2002). Moreover, smaller body size of first instar marks more difficulty in identification of living larvae. Previous studies (Bergvinson *et al.*, 1994, Coley and Barone 1996, Hariprasad and van Emdem 2010, Gotoh *et al.*, 2011 and Hong *et al.*, 2012) have shown that the fiber

content of leaves can affect the consumption of some Lepidoptera species and those hosts are representing an effective direct defense against herbivorous larvae. In this experiment the reproductive performance of survived insects was not studied.

### Host-plant preference for oviposition

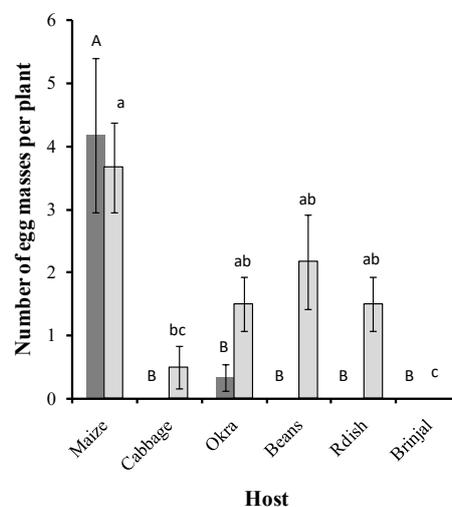
Among the tested vegetable crops in Choice experiment, *S. frugiperda* selected only maize and okra for oviposition (Figure 01 and Figure 02). Choice experiment suggested that female moths strongly preferred maize as their host than tested vegetables. Host preference for oviposition is highly varied with host plant quality. In general, female moths prefer oviposition on leaf surfaces where larval performance/ survival are greater (Craig *et al.*, 1992; Meagher *et al.*, 2004). This is in agreement with the present study; greater oviposition in maize under both free choice and

No-Choice experiments. Therefore, *S. frugiperda* female displays higher degree of preference/ specialization for the oviposition on maize. Rojas *et al.* (2018) indicated that oviposition by adult females was mediated by plant type, but not by seedling size and further said that ovipositional preference of females would positively be in relation with the performance of their larvae, including how larval performance takes place in the host. It also suggests that either ovipositing fall armyworm females discriminate among varieties or larvae preferentially select particular types of leaves in Wilmar *et al.* (2016). According to the Rojas *et al.* (2018) and Signoretti *et al.* (2012), the host-searching behavior of fall armyworm females has not been thoroughly investigated. But Carroll *et al.* (2006) reported that it has been shown that larvae can discriminate between healthy and herbivore-damaged plants and between different varieties of a plant according

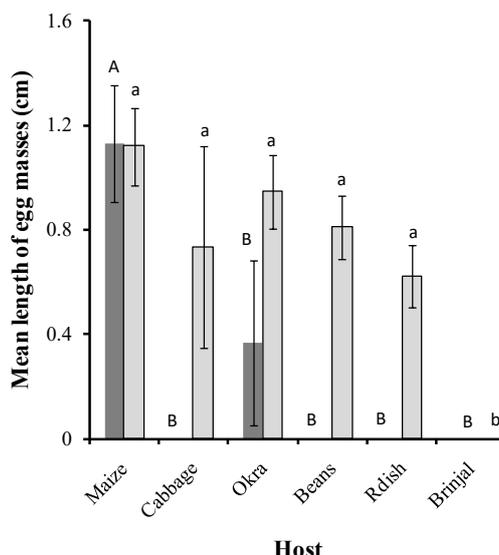
**Table 01: Male and female pupae weight (g) of *S. frugiperda* that feed on maize, cabbage, okra beans, radish and brinjal leaves under laboratory conditions.**

Host Plant	Male and Female Pupae Weight (g)	
	Male	Female
Maize	0.26±0.01a	0.22±0.005a
Cabbage	0.17±0.01b	0.18±0.005cb
Okra	*	0.14±0.01d
Beans	0.19±0.01b	0.13±0.01d
Radish	0.17±0.004b	0.15±0.01cd
Brinjal	0.18±0b	0.19±0.0b

Weights connected with same letters are not significantly different. (n=3). \*Male moths were not emerged from the treatment Okra



**Figure 01: Number *S. frugiperda* egg masses per plant at Choice test (dark gray) and No-Choice (light gray) on maize, cabbage, okra beans, radish and brinjal leaves under laboratory condition. Numbers of egg masses per plant connected with same letters are not significantly different. (n=3).**



**Figure 02.** Mean length of *S. frugiperda* egg masses at Choice test (dark gray) and No-Choice test (light gray) on maize, cabbage, okra beans, radish and brinjal under laboratory condition. Mean length of egg masses connected with same letters are not significantly different. (n=3).

to the results of Wilmar *et al.* (2015).

Egg masses were found in both sides of the leaf blade (upper and undersides) and this is in agreement with the findings of Silva *et al.* (2017). The number of eggs per egg mass and length of egg mass was not significantly different among the tested crops in No-Choice experiment. In No-Choice experiment oviposition was observed in all crops except brinjal. Therefore, in absence of preferred host (maize), okra, beans, radish and cabbage could act as an alternative host for *S. frugiperda*. Moreover, the result of present experiment suggested that, *S. frugiperda* may lay eggs in the alternative host in absence of their

preferred host maize and it is in agreement with Meagher *et al.* (2004).

**Feeding preference of neonate larvae to test crops**

The number of larvae that feed on different host plants after introduction and their damage was significantly different ( $p < 0.05$ ) among the hosts (Table 02 and Table 03). 1h, 3h, 24h and 48h after introduction, most number of the larvae was observed in maize and the lowest in brinjal. After one hour the number of larvae attracted to cabbage, okra and beans was not significantly different and Larvae were not examined on brinjal. After 3 hours the highest numbers of

**Table 02:** Distribution of *S. frugiperda* neonate larvae among host plants at 1h, 3h, 24h and 48h after introduction under laboratory conditions

Host	Mean Larvae count			
	After 1 hour	After 3 hours	After 24 hours	After 48 hours
Maize	2.9a	2.5a	3.7a	2.3a
Cabbage	1.7ab	2.0ab	2.1b	1.8a
Okra	1.6ab	1.8ab	1.5bc	1.6a
Beans	1.3ab	1.5abc	0.7bc	0.3b
Radish	0.5b	0.7bc	0.5c	0.2b
Brinjal	0.0b	0.2c	0.4c	0.1b
Total number of Dead larvae				

Means that do not share a letter are significantly different. (n=3)

**Table 03: Percentage of damage caused by *S.frugiperda* at 24h and 48 h after introduction on maize, cabbage, okra, beans, radish and brinjal under laboratory condition**

Host	Percentage of damage (%)	
	24 hours	48 hours
Maize	<25 %	<25 %
Cabbage	<25 %	<25 %
Okra	<25 %	50-75%
Beans	<25 %	25-50%
Radish	No significant damage	No significant damage
Brinjal	No significant damage	No significant damage

larvae were observed in the cabbage, okra and beans comparison to radish and brinjal among selected vegetables.

After 24 hours the highest number of larvae was observed in cabbage among vegetables. Most number of larvae was observed on maize, cabbage, okra was not significantly different after 48 hours and the lowest were examined in beans, radish and brinjal.

Results of the feeding preference test envisaged that there was no host dependent variability among neonate larvae for maize, cabbage, radish and brinjal. Although neonate larvae disperse on different hosts, the highest larval male and female survival (80%) was reported on maize in life cycle test. Less preference was examined for radish and brinjal in the preference test. Rojas *et al.* (2018) reported that, neonate larvae would randomly colonize the available hosts immediately, but following colonization they may disperse in search of a host more suitable than the colonized host and ovipositional preference of females positively align with the performance of their larvae. It includes how larval performance may

be mediated by expected (future) and ongoing (present) herbivory. Further they have identified neonate larvae would colonize hosts randomly and if they initially colonized poor hosts, older (3rd-instar) larvae orient towards and prefer hosts that would most favor their performance. When use of the 4 days old larvae for this experiment, larvae colonized on the maize and before end of the 24 hours, they feed on maize and damage was 100%. After that they dispersed for others and fed on those hosts.

## CONCLUSION

Greater oviposition, survival rate and shortest larva to adult period of *Spodoptera frugiperda* on maize indicate a higher host specialization/preference. However, with the absence of preferred host, *S. frugiperda* use cabbage, okra, beans and radish as alternative host for the oviposition among selected crops. Therefore, the use of these vegetables in cropping systems for crop rotation and inter cropping would create a positive impact on off season survival of *S.*

*frugiperda* by being alternative hosts. Result of this study concludes that growers should pay special attention when selecting vegetable crops in maize based upland cropping systems.

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