Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 13 [2] January 2024 : 141-145

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
ORIGINAL ARTICLE **OPEN ACCESS**

Understanding the Life history of Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) on Maize plantation in Raipur area of Chhattisgarh

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ABSTRACT
Fall Armyworm (FAW) is a very significant pest of Maize and is spread across the globe. Understanding the life cycle of this pest is essential for preventing its distribution. The present investigation was conducted during the Rabi season of 2021-22 and 2022-23 at the Instructional Research farm of Kalinga university, Raipur (C.G.). The incubation period of the eggs under laboratory conditions ranged to 2.48 ± 0.05 days. In laboratory and under the established ambient conditions, the life cycle (egg to adult) of S. frugiperda lasts a mean of 35.56 to 39.94 days on maize. The highest mortality of S. frugiperda was recorded in early larval stages (1st to 3rd larval instars) recording 80.63% followed by late larval stages i.e. 4th to 6th instars (51.92 %). However, the mortality in egg stage and pupal stage were recorded 15.44% and 5.26% respectively. Mortality in the egg stage was mainly due to sterility and unhatchability. The early instars recorded increased mortality due to dispersal, parasitism (Apantales spp) and infection by bacterial (Bacillus thuringiensis), viral (nuclear polyhedrosis virus) and fungal entomopathogens (Nomuraea rileyi and Beauveria bassiana). During the late larval stages especially in the 6th instar cannibalism was noticed on other larvae or the newly formed pupae even when food was not a limiting factor. There were other unknown causes which lead to increased mortality rates in the early and late larval stages.
Keywords: *Fall armyworm, Loss, Maize, Mortality, Research, Sterility*

Received 13.10.2023 Revised 03.11.2023 Accepted 27.12.2023

INTRODUCTION

Maize or corn (*Zea mays* L.) is a crop of global importance, which holds a unique position in world agriculture. Maize belongs to the family of Poaceae, originated from South America, from where it was taken to all parts of the world. Maize production and distribution is a cosmopolitan [1]. In India, maize after rice and wheat is the 3rd most important food crops accounting for about 20% of the global area under cereals. In India maize production estimated about 24.21 MMT in an area of 9.9 million hectares in 2020-21. In Chhattisgarh, it is well informed in an area of 226.79 hectare with productivity of 2458 kg/ha. of kharif season. Although 74.45 hectare area and 1950 kg/ha. productivity of rabi season in 2017-18 [2].

Fall armyworm, *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) is native to the Americas. Fall armyworm caterpillars are major pests of cereals and forage grasses and are recorded as eating 186 plant species from 42 families [3]. Fall armyworm is one of the most serious pests of maize in the America. Yield losses can reach 40% in Honduras and 72% in Argentina [4]. In addition to maize, fall armyworm attacks many other economically important, *e.g.* rice, sugarcane, sorghum, beet, tomato, potato, cotton and pasture grasses [5]. Therefore, fall armyworm could pose a risk to subsistence and cash crops in large parts of the world.

Understanding the factors that influence the distribution and abundance of an insect is a fundamental issue of insect ecology and is a practical concern with insects that cause economic damage [6]. This provides an opportunity for the development of management strategies significant for the control of these pests. These studies will support in devising the pest monitoring system and ecological sound integrated pest management modules. The reproductive potential, behavior, biology, fecundity, and fertility of the FAW have been studied which may be influenced by temperature, larval diet and the strain of FAW [7]. The aim of this study is to analyze the potential of maize crop as possible hosts of FAW and to evaluate their influence in different biological parameters when crops are utilized as food resource for this pest. The basic information on biology is required for the development of pest forewarning system so that efficient pest management tactics could be developed for pest.

MATERIAL AND METHODS

The biology of fall army worm, *Spodoptera frugiperda* will be studied under laboratory conditions at Kalinga University, Raipur in $25^0C \pm 2^0C$ temperature and 70 ± 5 per cent relative humidity. Twenty larvae will be provided with maize hybrid stem pieces for feeding. Stem pieces will be replaced with fresh food every day. Observations will be made twice a day to record incubation, larval and pupal periods, separately. Male and female adults emerged on maize will be allowed to mate separately and confined on leaf sheath in glass jar for egg laying. The eggs laid on maize will be kept separately and the incubation period will record. Separate sets of five pairs of moth will be kept to record the adult longevity. Honey solution will provide as adult food.

RESULTS AND DISCUSSION

A field experiment was conducted at Instructional Research farm of Kalinga universuty, Raipur (C.G.) during rabi 2021-22 and 2022-23 under laboratory conditions at Kalinga university, Raipur in $25^0C \pm 2^0C$ temperature and 70 ± 5 per cent relative humidity. The result obtained are presented and discussed in this chapter under the following heads.

Life History of *S. frugiperda*

The study on life table was conducted by maintaining cultures of *Spodoptera frugiperda* in the laboratory in $25^0C \pm 2^0C$ temperature and 70 ± 5 per cent relative humidity from field collected populations in the maize field of Kalinga universuty, Raipur.

The single sex method is adopted for the study of Life Table. The age specific life table was constructed by introducing five pairs of male and female into five wooden cages each measuring (length 34 cm x breadth 30 cm x height 60 cm). The forewing characteristics were used for identifying male and female insects. The adults moths were allowed to mate and females to oviposit till they died. The data on total no. of eggs laid were observed along with the survivability of eggs. The mortality rates of 1st to 6th instar larvae along with the adults were noted on a daily basis and the mortality factors were also ascertained.

The following biological parameters were observed:-

The incubation period of the eggs under laboratory conditions ranged to 2.48 ± 0.05 days. The first, second, third, fourth, fifth and sixth instar larva ranged to 2.37 ± 0.04, 1.95 ± 0.03, 1.70 ± 0.04, 1.83 ± 0.05, 2.15 ± 0.04 and 3.08 ± 0.09 days, respectively. The total larval period completed in 13.84 ± 0.13 days. The pupae were robust and reddish brown in color. The total pre-pupal and pupal duration ranged to 1.51 ± 0.06 and 9.26 ± 0.12 days, respectively in the laboratory. The male pupae were notably heavier compared to the female pupae when reared on maize. The adult female and male period was 12.85 ± 1.12 and 8.47 ± 1.29 days, respectively. In laboratory and under the established ambient conditions, the life cycle (egg to adult) of *S. frugiperda* lasts a mean of 35.56 to 39.94 days on maize.

The pre-oviposition and oviposition period was observed to 3.80 ± 1.38 and 9.17 ± 2.27 days, respectively. It is important to point out that after the pre-oviposition period, females did not lay eggs every day, and survived approximately two days after their last oviposition. The number of eggs laid by per female varied to 963.33 ± 233.53 and the number of egg masses laid by per female varied to 8.47 ± 2.85.

Table 1. Developmental time and longevity (Mean ± sd) of life stages of *S. frugiperda* fed on maize.

Stage (Days)	Maize (x ± sd)
Egg	2.48 ± 0.05
1st instar	2.37 ± 0.04
2nd instar	1.95 ± 0.03
3rd instar	1.70 ± 0.04
4th instar	1.83 ± 0.05
5th instar	2.15 ± 0.04
6th instar	3.08 ± 0.09
Larvae	13.84 ± 0.13
pre pupa	1.51 ± 0.06
Pupal stage	9.26 ± 0.12
Adult longevity	
female	12.85 ± 1.12
male	8.47 ± 1.29

Table 2. Population parameters of *S. frugiperda*, when the larvae were fed on maize.

Population parameters	Maize (x ± sd)
Pre-oviposition period	3.80 ± 1.38
Oviposition period	9.17 ± 2.27
Days that the female survives after carrying out last oviposition	1.93 ± 1.39
No. of eggs/female	963.33 ± 233.53
No. of egg masses/females	8.47 ± 2.85
No. of eggs/female/day	179.67 ± 69.67
No. of egg –masses /female/day	1.53 ± 0.38
No. of eggs/egg- masses	111.33 ± 96.64

Life table studies of *S. frugiperda*

The mortality and its factors was observed (Table 3) on different stages of development of *S. frugiperda* like egg, early larval stages, late larval stages and pupal stages of *S. frugiperda*. The highest mortality of *S. frugiperda* was recorded in early larval stages (1st to 3rd larval instars) recording 80.63 % followed by late larval stages *i.e.* 4th to 6th instars (51.92 %). However, the mortality in egg stage and pupal stage were recorded 15.44% and 5.26% respectively. Mortality in the egg stage was mainly due to sterility and unhatchability. The early instars recorded increased mortality due to dispersal, parasitism (*Apantales* spp) and infection by bacterial (*Bacillus thuringiensis*), viral (nuclear polyhedrosis virus) and fungal entomopathogens (*Nomuraea rileyi* and *Beauveria bassiana*). During the late larval stages especially in the 6th instar cannibalism was noticed on other larvae or the newly formed pupae even when food was not a limiting factor. There were other unknown causes which lead to increased mortality rates in the early and late larval stages Many reports suggested that a number of natural enemies and entomopathogens are found to infest the larvae of fall armyworm among which *Trichogramma* spp, *Telenomus* spp, *Campoletis chloridae*, *Apantales* spp and *Nomuraea rileyi* are very common in the field. This may pave the way to introduce bio-intensive pest management programme against fall armyworm. Table 4.13 depicts the trend index value (I) to be positive which indicates that the population of *S. frugiperda* would be much higher in the ensuing generations. Each egg in first generation will contribute 66.66% increase in egg production in the next generation. The survivorship curve denotes a type III curve (Figure 4.33) that indicates all late stages of the insects to be good survivors. This indicates that the 4th to 6th instars larvae are the major destructor of the crop. The patterns of survivorship observed indicated that the immature stages like egg and 1st to 3rd instars larvae are vulnerable to management practices.

There are limited reports on construction of life table for *S. frugiperda*. Similar trend was found in other study, where abiotic factors and predation had a greater effect on egg and early larval mortality. More than 95% of the mortality was recorded due to predation. Mortality in early larval population could not be replaceable as compared to egg mortality. Therefore, control measures in early larval stage may be more effective in reducing generational survival [8]. The late instars larvae of fall armyworm feeding on late whorl stage of the crop are difficult to be controlled by application of pesticide as penetration of pesticides were obstructed by the larval excreta (saw dust like frass) present in the whorl of maize plant. Therefore, it is easy to control 1st to 3rd instars larvae in early growth stage of the crop by application of pesticides [9].

Table 3: Life-table for *S. frugiperda* under laboratory conditions from field collected population

Age interval (x)	Number alive at the beginning of x	Number dying during x	Factor Responsible for D_x	D_x as % of l_x	Survival within x	Log of l_x	K-value	$(l_x + l_{x+1})/2$	$L_x + L_{x+1} + L_{x+2} .... + L_w$	(T_x / l_x)
X	l_x	D_x	D_xf	$100q_x$	S_x	Log x		L_x	T_x	e_x
Egg	1230	190	Sterility and unhatchibility	15.44	0.84	3.08	0.07	1135	4502	3.66
1st instar (N_1)	1040	230	dispersal	22.11	0.77	3.01	0.11	925	3367	3.23
2nd instar (N_2)	810	205	Bacterial, viral and fungal infections, parasitoids, unknown factors	25.3	0.74	2.9	0.12	707.5	2442	3.01
3rd instar (N_3)	605	201		33.22	0.66	2.78	0.18	504.5	1734.5	2.86
4th instar (N_4)	404	84		20.79	0.79	2.6	0.1	362	1230	3.04
5th instar (N_5)	320	56		17.5	0.82	2.5	0.08	292	868	2.71
6th instar (N_6)	264	36	Cannibalism	13.63	0.86	2.42	0.07	246	576	2.18
Pupal stage	228	12	Deformed pupae	5.26	0.94	2.35		222	330	1.44
Adult emerged	216 of which 109 ♀ & 107 ♂	Sex ratio:- Male : Female = 1: 0.98						108	108	0.5

- K = age specific key mortality
- X = the pivotal age for the age class in units of time (days)
- l_x = the number surviving at the beginning
- D_x= the number dying during the age interval x,
- e_x = the expectancy of life remaining for individual age x given by formula (T_x / l_x)
- K = age specific key mortality, It is a key factor which is primarily responsible for increase or decrease in number from one generation to another and was computed as difference between successive values for 'log lx'. However, the total generation mortality was calculated by adding "K" values of different development stages.
- L_x= the number remain alive in between ages x and x+1 = $(l_x + l_{x+1})/2$
- T_x = total number at age x units beyond the age x is calculated as $T_x = L_x + L_{x+1} + L_{x+2} + ... + L_w$ *i.e.* cumulative sum from bottom

Table 4: Life-table for *S. frugiperda* under laboratory conditions from field collected population.

Seasonal reproductive rate	No. of females emerged/ total no. of eggs observed in first generation	13.29 %
Mean fecundity of the cohort	Average no. of eggs produced by a female x no. of females. (Total no. of eggs laid) (where average fecundity is 820)	89,380
Trend index (I)	No. of eggs produced by female cohort/ No. of eggs started life in first generation.	66.66%
Generation survival	Total no. of males and females observed/ No. of first instar observed in first generation.	0.17

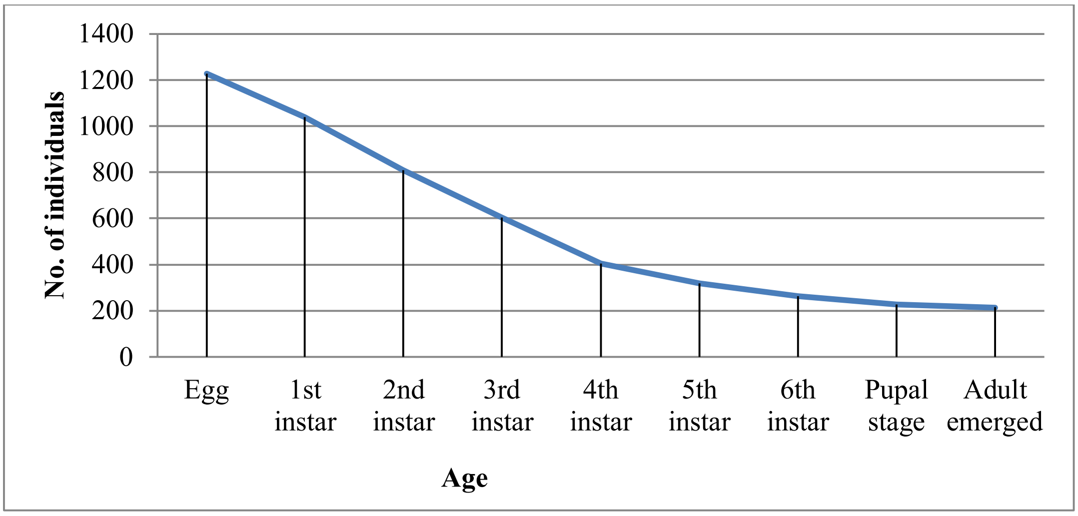

Fig 1- Survivorship Curve of *S. frugiperda*

CONCLUSIONS

The incubation period of the eggs under laboratory conditions ranged to 2.48 ± 0.05 days. The total larval period completed in 13.84 ± 0.13 days. The total pre-pupal and pupal duration ranged to 1.51 ± 0.06 and 9.26 ± 0.12 days, respectively in the laboratory. The male pupae were notably heavier compared to the female pupae when reared on maize. The adult female and male period was 12.85 ± 1.12 and 8.47 ± 1.29 days, respectively. In laboratory and under the established ambient conditions, the life cycle (egg to adult) of *S. frugiperda* lasts a mean of 35.56 to 39.94 days on maize. The highest mortality of *S. frugiperda* was recorded in early larval stages (1st to 3rd larval instars) recording 80.63 % followed by late larval stages *i.e.* 4th to 6th instars (51.92 %). However, the mortality in egg stage and pupal stage were recorded 15.44% and 5.26% respectively.

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CITATION OF THIS ARTICLE

Kapil Dev D, Ajay K H, Manoj S. Understanding the Life history of Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) on Maize plantation in Raipur area of Chhattisgarh. Bull. Env. Pharmacol. Life Sci., Vol 13[2] January 2024:141-145