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Biology and morphometrics characteristics of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) reared on fodder oat genotypes under laboratory conditions

Payal Sharma, SB Das, Gopilal Anjana and Deepali Vishwakarma

Abstract
The fall army worm (FAW) *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is a polyphagous pest and it has a high preference for oat (*Avena sativa* L.) crop. The biology and morphometrics characteristics of *Spodoptera frugiperda* (J. E. Smith) reared on fodder oat genotypes *viz.* JO-1, JO-2, JO-5, JO03-91, JO03-93, Kent, OS-6 and UPO-212 were studied during *rabi* 2020-21, under laboratory conditions. Among the eight fodder oat genotypes, three genotypes *viz.* Kent, OS-6 and UPO-212 were found to be highly susceptible to *S. frugiperda* and JO-1, JO-2 and JO-5 were found to be least susceptible. Gravid female preoviposition period and oviposition period was non-significant. The mean number of egg clusters and egg laid per female ranged from 4.67 to 8.33, 76.56 to 293.11 respectively. Incubation, total larval, pupal, male and female adult longevity period were significantly observed to be from 3.23 to 3.57, 14.93 to 19.57, 7.54 to 8.85, 5.84 to 7.98 and 7.23 to 8.64 days respectively in different genotypes. Morphometrics characteristics head capsule width (HCW), body length (BL) and body width (BW) observed were significantly in different genotypes of fodder oat. The male pupal length and width ranged from 11.750 mm to 12.443 mm and 4.225mm to 5.411 mm respectively, while for female pupae it ranged from 13.922 mm to 15.771 mm and 4.277 mm to 5.665 mm respectively. The wing expansion and body length of male moths significantly ranged from 27.57 mm to 29.39 mm and 11.86 mm to 14.15 mm, while for female it was 28.09 mm to 29.76 mm and 12.66 mm to 14.95 mm respectively. The findings of the present investigation are useful to design an integrated management protocol for the fall army worm in oat crop.

Keywords: Fall army worm, oat, biology, morphometrics, laboratory

Introduction
Oat (*Avena sativa* L.) is a cereal crop, belonging to the family Poaceae. It has a highly nutritive value (Alemayehu *et al*., 2023) [1]. Oat is ranked sixth in the world cereal production, after wheat, rice, maize, barley and sorghum (Devi *et al*., 2019; Ishan *et al*., 2022) [7, 11]. In many parts of the world, oats are grown for use as grain as well as for forage and fodder, straw for bedding, hay, haylage, silage and chaff. Livestock grain feed is still the primary use of oat crops, accounting for an average of around 74% of the world's total usage (Sandhya *et al*., 2020) [24].

Oats crop is invaded by various kinds of pests and fall army worm is one amongst them. The fall army worm (FAW) *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is a polyphagous pest. Economic losses due to different polyphagous pests are reported in a variety of crops such as maize, soybean, cotton and beans (Pogue, 2002; Nagoshi, 2007; Bueno *et al*., 2010) [22, 18, 6] and number of weeds including Ipomoea and other grasses (Nabity *et al*., 2011) [17]. *S. frugiperda* feeds on 186 plant species from 42 families (Narayanamma *et al*., 2020) [20]. The occurrence of this new invasive pest was reported for the first time from India by Sharanabasappa and Kalleshwaraswamy (2018) [26]. The pest has high preference for oat crop (Silva *et al*., 2017) [30]. Biology of FAW as occurring in India is important for identifying the life stages. Hence, the study on the biology and biometric characteristics of *Spodoptera frugiperda* reared on fodder oat genotypes under laboratory conditions was performed in the present study.

Materials and Methods
Initial culture as egg masses and third and fourth instar larvae of *S. frugiperda* were collected from All India Coordinated Research Project (AICRP) on fodder crops field, and were reared in the Biocontrol Laboratory, Department of Entomology, College of Agriculture, Jawaharlal

Nehru Krishi Vishwa Vidyalaya, Jabalpur to study the biology and morphometrics on fodder oat genotypes *viz.* JO-1, JO-2, JO-5, JO03-91, JO03-93, Kent, OS-6 and UPO-212. Larvae and egg masses were transferred to a clean plastic jar by providing fresh and soft fodder oat leaves lined with moist filter paper and covered with muslin cloth. Larvae were reared as suggested by Santos *et al*., (2003) [25]. Rearing jars were cleaned with 2% formaldehyde (excreta and filter paper was changed regularly) and fresh food was supplied daily to maintain good conditions for the developing larvae. When the larvae were about to enter into the pre-pupal stage, they were transferred to another plastic jars with bottom lining of moistened filter paper and a 5-6 cm thick layer of soil underneath to facilitate pupation. The pupae were collected after 3 days of pupation and transferred to egg laying chambers for adult emergence and egg laying (Marcela and Mario 2020) [15]. Immediately after the emergence of the moths, male and female moths were released into a separate egg laying plastic jar. A piece of cotton soaked in 50% honey solution was kept inside the jar as a food source for the emerging adults, which were covered with muslin cloth as suggested by Manjula *et al*., (2019) [14]. The treatments were replicated thrice for observing oviposition period, fecundity, viability of eggs, adult male and female longevity.

Morphometrics of different stages *viz.*, larva, pupa and adult of *S. frugiperda* on different oat genotypes were recorded by graphical method. For measuring the length, width and head capsule width of larvae they were transferred on graph paper and the observations were recorded. Pupal length and width and adult body length and wing span of both female and male moths were measured with the help of vernier calipers as suggested by Ramaiah and Maheswari (2018) [23].

A. Biometrical observations

The applicability of Dyar's law was validated for the head capsule width of each instar and was computed as proposed by Shull *et al*., (2010) [28]. Similarly, the applicability of Przibram and Megusar's rule was validated for larval body length and width, and the regression lines were obtained to test the applicability of the above-mentioned law/rule, and the following parameters were calculated as suggested by Vashisth and Chandel (2013) [32]. Different related calculations were carried out according to the following formula:

$$\text{Growth ratio} = \frac{\text{Value of succeeding instar}}{\text{Value of preceding instar}}$$

Difference = Observed values of instar – Estimated value of instar

$$\text{Difference (\%)} = \frac{\text{Difference}}{\text{Estimated value}} \times 100$$

Progression factor = Regression factor = b

B. Voracity studies

Initial weight of food supplied, weight of uneaten/ leftover food, faecal weight, fresh weight of the surviving larvae and duration of feeding period were recorded instar wise, daily on all the genotypes as per the methodology suggested by Silva *et al*., (2017) [30].

Physiological indices

From the above observations, nutritional indices were computed as proposed by Xue *et al*., (2009) [35] and Narvekar *et al*., (2018) [21] with following equations:

$$\text{Consumption Index (CI)} = \frac{F}{TA}$$

$$\text{Relative Growth Rate (RGR)} = \frac{\text{G}}{\text{TA}}$$

$$\text{Approximate Digestibility (AD)} = \frac{(\text{F}-\text{H})}{\text{F}} \times 100$$

$$\text{Efficiency of Conversion of Ingested Food (\%) (ECI)} = \frac{G}{F} \times 100$$

$$\text{Efficiency of Conversion of Digested Food \% (ECD)} = \frac{\text{G}}{\text{F}-\text{H}} \times 100$$

Where,

F = Average weight of leaves consumed by a larva (mg)

T = Duration of feeding on different genotypes (days)

A = Average weight of one larva on different genotypes (mg)

G = Average weight gained by larva during feeding period (mg)

H = Average weight of faecal matter excreted by larva (mg)

For computing the undermentioned indices, the variety OS-6 was used as standard reference because of its higher susceptibility to *S. frugiperda*.

$$\text{Larval Pupal Index} = \frac{\text{Ava.larval period on OS}-6 + \text{Ava.pupal period on OS}-6}{\text{Ava.larval period on test plant} + \text{Ava.pupal period on test plant}}$$

$$\text{Pupal Weight Index} = \frac{\text{Ava.pupal weight on test plant (mg)}}{\text{Ava.pupal weight on OS}-6\text{ (mg)}}$$

$$\text{Adult Index} = \frac{\text{Ava.adult longevity on test plant (days)}}{\text{Ava.adult longevity on OS}-6\text{ (mg)}}$$

$$\text{Survival Index} = \frac{\text{The no.of adult emerged from larvae on test plant}}{\text{The no.of adult emerged from larvae on OS}-6}$$

$$\text{Ovipositional Index} = \frac{\text{Ava.no.of eggs laid on test plant}}{\text{Ava.no.of eggs laid on OS}-6}$$

Biological Growth Indices

From the above observations the growth indices were calculated as suggested by Khedr *et al*., (2015) [13].

$$\text{Growth Index} = \frac{\text{Pupation (\%)}}{\text{Larval period (days)}}$$

$$\text{Standardized Growth Index} = \frac{\text{Pupal weight (mg)}}{\text{Larval period (days)}}$$

$$\text{Fitness Index} = \frac{\text{Pupation \% x pupal weight (mg)}}{\text{Larval period days + pupal period (days)}}$$

Population parameter of *S. frugiperda*

Various population growth parameters *viz.*, net reproductive rate, intrinsic rate of increase, finite rate of increase, mean generation time and doubling time were computed with the software lifetable calculator (www.icar.crida.).

Results and Discussion

Biology and Morphometrics of *S. frugiperda*

Preoviposition and Oviposition period

Preoviposition period was ranged between 2.33 days (JO-2 and UPO-212) to 2.67 days (JO-5 and Kent). While the oviposition period ranged from 2.93 days (JO-1) to 4.13 days (OS-6), respectively (Table 1). The present results are in agreement with the results obtained by Siddhapara *et al*., (2020) [29] as they reported that preoviposition and oviposition

periods were 3.50 and 3.20 days, respectively on maize. Whereas, Manjula *et al*., (2019) [14] reported that the preoviposition period of *S. frugiperda* was 2-4 days on maize. According to a recent experiment conducted by Gebretsadik *et al*., (2023) [8] when different cereal hosts were compared for preoviposition and oviposition periods the results were different from each other. As preoviposition of *S. frugiperda* was when compared to maize leaves (2.84 d) and barley (3.06 d) feed, it was noticeably longer ($p < 0.001$) in barley. In comparison to those fed on other host plants, the oviposition of *S. frugiperda* fed on barley (35.26 d) and faba beans (37.63 d) were seen to be much longer. For *S. frugiperda*, the oviposition duration was considerably longer (6.16 d).

Egg stage

S. frugiperda female moth laid eggs in masses, preferably on the under or upper surface of leaves which were covered with buff-colored abdominal hairs. Eggs were round and greenish white in color. Similar findings have been documented by Sharanabasappa *et al*., (2018) [26].

No. of egg clusters laid per female

The mean number of egg clusters laid per female significantly ranged from 4.67 on (JO-1 and JO-5) to 8.33 (OS-6). The present findings are in accordance with the findings of Xue *et al*., (2010) [35], as they also claimed that about 4.7 egg clusters were laid by *S. litura* on tobacco.

No. of eggs laid per cluster per female

The eggs/masses laid by female *S. frugiperda* moths ranged from 76.56 to 293.11. The present findings confirm the findings of Igyuve *et al*., (2018) [10] and Sharanabasappa *et al*., (2018) [26] as they reported that the number of eggs per cluster on maize ranged from 150-200 and 55 to 888, respectively.

Incubation period

Incubation period on different oat genotypes ranged from 3.23 days (JO03-93 and Kent) to 3.57 days (JO03-31) (Table 1). The present findings are in agreement with the findings of Helen *et al*., (2021) [9] as they also reported that the incubation period was 3.30 ± 0.65 days on maize.

Hatching

The hatching of *S. frugiperda* eggs on different oat genotypes differed significantly and it ranged from 72.37% (JO-5) to 93.7% (OS-6). Similar findings have been documented by Tiwari at el., (2020) [31] and Helen *et al*., (2021) [9] as they reported it to range from 84.34 to 93.85% on fodder maize and 96% on maize, respectively.

Larval stage

Larval survival

The survival of first to sixth instar larvae was maximum on Kent (82.22, 64.44, 53.63, 46.08, 44.63 and 44.0%, respectively) while, it was minimum on JO03-93 (71.11, 53.33, 38.95, 32.48, 26.97 and 24.62%, respectively) The present findings for larval survival are confirms the findings of Borigas *et al*., (2013) [5] and Wang *et al*., (2020) [33] as they reported it to be 46% (rice) and 38.6% on wheat, respectively.

Larval developmental period

In the present study, *S. frugiperda* larval development was completed with five moultings, resulting into six larval instars on fodder oat genotypes. The present findings are in accordance with the findings of Sharanabasappa *et al*., (2018) [26] and Siddhapara *et al*., (2021) [29]. The developmental period of *S. frugiperda* larvae significantly ranged from 14.93 days (OS-6) to 19.57 days (JO-2). The larval duration of first to sixth instar larvae ranged from 3.23 (JO03-93 and Kent) to 3.57 days (JO03-91), 2.43 days (UPO-212 and OS-6) to 3.13 days (JO-5), 2.10 (JO03-91 and Kent) to 2.63 days (JO-2), 2.17 (UPO-212 and OS-6) to 2.60days (JO03-91), 2.43 (Kent) to 3.60 days (JO03-91) and 2.73 (OS-6) to 3.77 days (JO-5), respectively (Table 1). The total developmental period are in conformity with the findings of Helen *et al*., (2021) [9] as they also reported that the larval duration ranged from 2.5 to 3, 2.5 to 3, 2 to 2.5, 2 to 2.5, 2.5 to 3, 4.5 to 5 and 16 to 18 days, respectively. Similar results have been reported by several workers *viz.*, Silva *et al*., (2017) [30], Sharanabasappa *et al*., (2018) [26] and Siddhapara *et al*., (2021) [29].

Morphometrics of *S. frugiperda* larvae

First instar

The head capsule width (HCW), body length (BL) and body width (BW) of first instar larvae significantly ranged from 0.291 (JO-2) to 0.335 mm (OS-6), 0.943 (JO-1) to 1.333 mm (UPO-212) and 0.219 (JO03-93) to 0.246 mm (UPO-212), respectively (Table 2). These results confirm the findings of Igyuve *et al*., (2018) [10] and Siddhapara *et al*., (2021) [29] on maize crop. Similar findings have been documented by Assefa and Ayalew (2019) [2]. They also reported that the HCW, BL and BW of first instar larvae were 0.25 mm, 1.50 mm and 0.24 mm, respectively.

Second instar

The HCW, BL and BW of second instar larvae significantly ranged from 0.379 to 0.417 mm (JO-2 and UPO-212, respectively); 2.867 to 3.400 mm (JO-2 and UPO-212) and 0.321 (JO03-91) to 0.355 mm (JO-5), respectively. Similar results have been published by Igyuve *et al*., (2018) [10] and Siddhapara *et al*., (2021) [29], as they also reported that the HCW, BL and BW of second instar larvae to be 0.37 mm, 4.45 mm and 0.52 mm respectively. Our data is also in agreement with the findings of Manjula *et al*., (2019) [14] as they also reported that body length and HCW was 3.7 mm and 0.5 mm, respectively.

Third instar

In the present category it is observed that the HCW, BL and BW significantly ranged from 0.667 (JO-5) to 0.728 mm (OS-6), 5.433 (JO-2) to 6.633 mm (UPO-212) and 0.828 (JO-5) to 0.873 mm (OS-6), respectively. Similar results have been claimed by Assefa and Ayalew (2019) [2] and Montezano *et al*., (2019) [16].

Fourth instar

Under this category, the present findings indicate that the HCW, BL and BW significantly ranged from 1.156 mm (JO-1) to 1.313 mm (UPO-212), 9.133 mm (JO-2) to 10.400 mm (OS-6) and 1.814 mm (JO-3) to 1.872 mm (OS-6), respectively. These results are in agreement with the findings of Igyuve *et al*., (2018) [10] and Siddhapara *et al*., (2021) [29] as they also reported that the HCW, BL and BW of fourth instar larvae were 0.70, 23.15 and 3.51 mm, respectively. Our data is also in conformity with the findings of Marcela and Mario (2020) [15]. They reported that the HCW, BL and BW were 0.95 mm, 14.57-16.66 mm and 1.68 to 2.04 mm, respectively.

Fifth and sixth instar

The HCW, BL and BW of fifth instar larvae significantly ranged from 1.770 mm (JO-2) to 2.013 mm (UPO-212), 16.200 mm (JO-2) to 17.467 mm (OS-6) and 2.513 mm (JO-5) to 3.332 mm (UPO-212), respectively. Similarly for sixth instar larvae it was 2.133 mm (JO-1) to 2.347 mm (UPO-212), 28.233 mm (JO-5) to 30.367 mm (OS-6) and 3.682 mm (JO-5) to 4.657 mm (UPO-212), respectively. Similar findings have been claimed by Igyuve *et al*., (2018) [10] and Marcela and Mario (2020) [15].

Pupae

Pupation

The pupation of *S. frugiperda* fed on different fodder oat genotypes ranged from 85.00% (JO-1) to 94.33% (JO03-91) (Table 3). The present findings are in close proximity with the findings of Montezano *et al*., (2019) [16] as they reported it to be 97.95%. The slight variation in the pupation might be due to the variability in the preference of the genotypes by the pest.

Pupal period

S. frugiperda pupal period on different fodder oat genotypes ranged from 7.54 (OS-6) to 8.85 days (Kent) (Table 1). The results of the present study are in conformity with the findings of Sliva *et al*., (2017), Bhusal and Bhattarai (2019) [4] and Kalyan *et al*., (2020) [12] as they reported it to be 8.86, 8.54 and 8.96 days, respectively. Slight variation in the present studies in some of the biological parameters might be due to the variability in the preference of the genotypes by the pest.

Morphometrics of pupae

The *S. frugiperda* male pupal length and width on different fodder oat genotypes ranged from 11.750 mm (JO03-91) to 12.443 mm (UPO-212 and JO03-93) and 4.225mm (JO-2) to 5.411 mm (UPO-212), respectively, while for female pupae it ranged from 13.922 mm (JO-5) to 15.771 mm (OS-6) and 4.277 mm (JO-1) to 5.665 mm (UPO-212), respectively (Table 4). The present findings corroborate the findings of by Igyuve *et al*., (2018) [10], as they also reported that the pupal length ranged from 14-18 mm and the width was 4.5 mm.

Adult

Adult emergence

The *S. frugiperda* adult emergence among the fodder oat genotypes significantly ranged from 72.23% (JO-1) to 94.43% (UPO-212) (Table 3). The present findings corroborate the findings of Naik *et al*., (2017) [19], as they reported that the adult emergence of *S. litura* on vegetable soybean ranged from 71.04 to 75.06%.

Adult longevity

The *S. frugiperda* male and female adult longevity on different oat genotypes significantly ranged from 5.84 (JO-5) to 7.98 days (OS-6) and 7.23 (JO-2) to 8.64 days (UPO-212), respectively (Table 1). The male longevity was observed to be significantly less than the female moths. The present findings are in agreement with the findings of and Sharanabasappa *et al*., (2018) [26], Bhusal and Bhattarai (2019) [4] and Siddhapara *et al*., (2021) [29] According to their findings the female and male longevity were ranged from 9-12 and 7-9 days respectively.

Morphometry of adult

The wing expansion and body length of male moths significantly ranged from 27.57 mm (JO-1) to 29.39 mm (Kent) and 11.86 mm (JO-2) to 14.15 mm (UPO-212), while for female it was 28.09 mm (OS-6) to 29.76 mm (Kent) and 12.66 mm (JO-1) to 14.95 mm (UPO-212), respectively (Table 4). The present findings indicate that the female moths are stouter than the male moths and the findings are in accordance with that of Kalyan *et al*., (2020) [12]. They reported that the body length of male and female moth ranged from 14-17 mm and 13-17 mm, while the wingspan varied from 29-35 mm and 29-34 mm, respectively.

Table 1: Impact of fodder oat genotypes on developmental period of different life stages of *S. frugiperda*

Fodder oat genotypes	Developmental period (days)*												
	Pre oviposition	Oviposition	Incubation period (days)*	Larval instars							Pupa	Adult (A)	Total (E-A)
				1st	2nd	3rd	4th	5th	6th	Total			
JO-1	2.47 (1.86)	2.93 (1.98) ^{d}	3.50 (2.12) ^{a}	2.77 (1.94) ^{cd}	2.73 (1.93)^{bc}	2.27 (1.81) ^{b}	2.23 (1.80) ^{c}	3.17 (2.04) ^{c}	3.63 (2.15) ^{b}	16.80 (4.22) ^{d}	8.07 (3.01)^{bc}	7.13 (2.85) ^{cd}	35.67 (6.05) ^{de}
JO-2	2.33 (1.83)	3.07 (2.02) ^{cd}	3.50 (2.12) ^{a}	3.27 (2.07) ^{b}	2.83 (1.96) ^{b}	2.63 (1.91) ^{a}	2.53 (1.88) ^{a}	3.57 (2.14) ^{a}	4.73 (2.39) ^{a}	19.57 (4.54) ^{a}	8.25 (3.04) ^{ab}	6.80 (2.79) ^{de}	37.97 (6.24) ^{a}
JO-5	2.67 (1.91)	3.33 (2.08) ^{bcd}	3.30 (2.07) ^{b}	3.60 (2.14) ^{a}	3.13 (2.03) ^{a}	2.53 (1.88) ^{a}	2.30 (1.82) ^{b}	3.43 (2.11) ^{ab}	3.77 (2.18) ^{b}	18.77 (4.45) ^{b}	8.18 (3.03) ^{abc}	6.38 (2.72) ^{e}	36.99 (6.16) ^{b}
JO03-91	2.60 (1.90)	3.20 (2.05) ^{bcd}	3.53 (2.13) ^{a}	2.67 (1.91) ^{d}	2.70 (1.92) ^{cd}	2.10 (1.76) ^{b}	2.60 (1.90) ^{a}	3.60 (2.14) ^{a}	3.67 (2.16) ^{b}	17.33 (4.28) ^{c}	8.49 (3.08) ^{ab}	7.53 (2.92) ^{bc}	36.68 (6.14) ^{bc}
JO03-93	2.80 (1.95)	3.20 (2.05) ^{bcd}	3.57 (2.14) ^{a}	3.20 (2.05) ^{b}	2.57 (1.89) ^{de}	2.20 (1.79) ^{b}	2.27 (1.81)^{bc}	3.27 (2.07) ^{bc}	3.60 (2.14) ^{b}	17.1 (4.25) ^{cd}	8.33 (3.05) ^{ab}	7.66 (2.94) ^{abc}	35.99 (6.08) ^{cd}
Kent	2.67 (1.91)	3.53 (2.13) ^{bc}	3.23 (2.06) ^{b}	2.77 (1.94) ^{cd}	2.73 (1.93) ^{bc}	2.10 (1.76) ^{b}	2.23 (1.80) ^{bc}	2.43 (1.85) ^{e}	3.17 (2.04) ^{c}	15.43 (4.05) ^{f}	8.85 (3.14) ^{a}	7.50 (2.92) ^{bc}	35.12 (6.01) ^{ef}
OS-6	2.40 (1.84)	4.13 (2.27) ^{a}	3.23 (2.06) ^{b}	2.80 (1.95) ^{c}	2.43 (1.85) ^{e}	2.23 (1.80) ^{b}	2.17 (1.78) ^{c}	2.57 (1.89) ^{de}	2.73 (1.93) ^{d}	14.93 (3.99) ^{g}	7.54 (2.92) ^{c}	8.29 (3.05) ^{a}	34.24 (5.94) ^{f}
UPO-212	2.33 (1.83)	3.60 (2.14) ^{b}	3.53 (2.13) ^{a}	2.73 (1.93) ^{cd}	2.43 (1.85) ^{e}	2.27 (1.81) ^{b}	2.17 (1.78) ^{c}	2.63 (1.91) ^{d}	3.60 (2.14) ^{b}	15.83 (4.10) ^{e}	8.02 (3.00) ^{bc}	8.13 (3.02) ^{ab}	35.18 (6.01) ^{ef}
S. Em±	0.038	0.035	3.27 (2.07) ^{b}	0.011	0.012	0.017	0.011	0.016	0.014	0.01	0.04	0.032	0.04
CD at 5%	NS	0.105	0.02	0.033	0.037	0.049	0.033	0.049	0.042	0.04	0.11	0.068	0.13

*= Figures in parentheses are square root transformed values

As per DMRT test (P<0.05) means within column followed by similar alphabets are non-significant

Table 2: Impact of fodder oat genotypes on mean head capsule width, Mean of body length, Mean body width of different larval instars

Fodder oat genotypes	Mean head capsule width (mm)*						Mean of body length (mm)*						Mean body width (mm)*					
	1st	2nd	3rd	4th	5th	6th	1st	2nd	3rd	4th	5th	6th	1st	2nd	3rd	4th	5th	6th
JO-1	0.295 (1.14)^{c}	0.410 (1.19)^{a}	0.701 (1.30)^{b}	1.156 (1.47)^{f}	1.799 (1.67)^{cd}	2.133 (1.77)^{e}	0.943 (1.39)^{e}	3.100 (2.02)^{bc}	5.733 (2.59)^{d}	9.200 (3.19)^{e}	16.267 .(4.16)^{c}	28.967 (5.47)^{b}	0.231 (1.109)	0.326 (1.151)	0.833 (1.151)^{de}	1.826 (1.681)^{de}	2.546 (1.883) ^{c}	3.704 (2.169) ^{c}
JO-2	0.291 (1.14)^{c}	0.388 (1.17)^{c}	0.690 (1.30)^{b}	1.178 (1.48)^{df}	1.770 (1.66)^{d}	2.187 (1.79)^{c}	0.963 (1.40)^{e}	2.867 (1.97)^{d}	5.433 (2.54)^{e}	9.133 (3.18)^{e}	16.200 (4.15)^{c}	28.733 (5.45)^{b}	0.234 (1.111)	0.344 (1.159)	0.848 (1.159) ^{cd}	1.815 (1.678) ^{e}	2.883 (1.971) ^{b}	3.728 (2.174) ^{c}
JO-5	0.302 (1.14)^{c}	0.396 (1.18)^{b}	0.675 (1.29)^{c}	1.206 (1.49)^{de}	1.820 (1.68)^{c}	2.190 (1.79)^{c}	1.00 (1.42)^{d}	3.067 (2.02)^{bcd}	5.667 (2.58)^{d}	9.467 (3.24)^{d}	16.400 (4.17)^{c}	28.233 (5.41)^{b}	0.220 (1.105)	0.355 (1.164)	0.828 (1.164) ^{e}	1.814 (1.677) ^{e}	2.513 (1.874)^{c}	3.682 (2.164)^{c}
JO03-91	0.312 (1.15)^{b}	0.387 (1.17)^{c}	0.684 (1.30)^{b}	1.182 (1.48)^{df}	1.927 (1.71)^{b}	2.176 (1.78)^{d}	1.040 (1.43)^{d}	3.000 (2.00)^{cd}	5.933 (2.63)^{c}	9.600 (3.26)^{cd}	16.833 (4.22)^{b}	28.567 (5.44)^{b}	0.224 (1.106)	0.321 (1.149)	0.840 (1.149)^{cde}	1.847 (1.687) ^{c}	3.124 (2.030)^{ab}	3.880 (2.208)^{bc}
JO03-93	0.321 (1.15)^{b}	0.378 (1.18)^{c}	0.678 (1.29)^{c}	1.211 (1.49)^{d}	1.937 (1.71)^{b}	2.211 (1.79)^{c}	1.147 (1.47)^{c}	3.167 (2.04)^{bc}	6.100 (2.66)^{bc}	9.733 (3.28)^{c}	16.900 (4.23)^{b}	30.067 (5.57)^{a}	0.219 (1.104)	0.328 (1.152)	0.841 (1.152)^{cde}	1.844 (1.686)^{cd}	3.209 (2.051)^{ab}	3.693 (2.166)^{c}
Kent	0.325 (1.15)^{b}	0.403 (1.19)^{a}	0.707 (1.31)^{a}	1.250 (1.50)^{c}	1.979 (1.73)^{a}	2.314 (1.82)^{b}	1.180 (1.48)^{c}	3.267 (2.07)^{ab}	6.167 (2.68)^{b}	10.000 (3.32)^{b}	16.933 (4.23)^{b}	30.233 (5.59)^{a}	0.237 (1.112)	0.371 (1.171)	0.852 (1.171) ^{bc}	1.853 (1.689)^{bc}	2.985 (1.996)^{ab}	4.092 (2.256)^{b}
OS-6	0.335 (1.16)^{a}	0.414 (1.18)^{b}	0.715 (1.31)^{a}	1.269 (1.51)^{b}	2.006 (1.73)^{a}	2.343 (1.83)^{a}	1.273 (1.51)^{b}	3.400 (2.10)^{a}	6.533 (2.74)^{a}	10.400 (3.38)^{a}	17.467 (4.30)^{a}	30.367 (5.60)^{a}	0.231 (1.110)	0.352 (1.163)	0.873 (1.163) ^{a}	1.872 (1.695)^{a}	3.128 (2.032)^{ab}	4.515 (2.348)^{a}
UPO-212	0.310 (1.14)^{c}	0.417 (1.19)^{a}	0.706 (1.31)^{a}	1.313 (1.52)^{a}	2.013 (1.74)^{a}	2.347 (1.83)^{a}	1.333 (1.53)^{a}	3.400 (2.10)^{a}	6.633 (2.76)^{a}	10.267 (3.36)^{a}	17.367 (4.29)^{a}	29.867 (5.56)^{a}	0.246 (1.116)	0.353 (1.163)	0.867 (1.163) ^{ab}	1.865 (1.693)^{ab}	3.332 (2.081) ^{a}	4.657 (2.378)^{a}
SEm±	0.002	0.002	0.002	0.003	0.005	0.003	0.006	0.015	0.011	0.013	0.016	0.022	0.003	0.013	0.002	0.002	0.027	0.024
CD at 5%	0.006	0.007	0.005	0.009	0.015	0.009	0.018	0.046	0.033	0.038	0.048	0.065	NS	NS	0.005	0.006	0.082	0.073

* = Figures in parentheses are square root transformed values

As per DMRT test (p<0.05) means within column followed by similar alphabets are non-significant

Table 3: Impact of fodder oat genotypes on *S. frugiperda* pupal development, sex ratio, longevity of adult moths and survival percent

Fodder oat genotypes	Pupation (%) #	Formation of pupa of different sexes (%) #			Total life span of moths (days)		Adult emergence (%)#	Total survival (%) #
		Male (M)	Female (F)	F:M	Male	Female		
JO-1	85.00 (67.40) ^{a}	43.333 (41.154) ^{c}	56.667 (48.846) ^{f}	1:0.76	34.98 (6.00) ^{bc}	36.37 (6.11) ^{bc}	72.23 (58.22) ^{a}	24.44 (29.58) ^{b}
JO-2	86.67 (68.86) ^{ab}	53.333 (46.923) ^{d}	46.667 (43.077) ^{e}	1:1.14	37.58 (6.21) ^{a}	38.35 (6.27) ^{a}	83.31 (65.90) ^{acd}	26.67 (31.09) ^{b}
JO-5	93.33 (75.24) ^{bc}	55.556 (48.245) ^{f}	44.444 (41.755) ^{c}	1:1.25	36.19 (6.10) ^{ab}	37.80 (6.23) ^{ab}	72.26 (58.22) ^{ab}	24.44 (29.58) ^{b}
JO03-91	94.33 (77.21) ^{c}	35.556 (36.587) ^{a}	64.444 (53.413) ^{h}	1:0.55	36.07 (6.09) ^{ab}	37.30 (6.19) ^{abc}	88.33 (70.15) ^{de}	31.11 (33.87) ^{ab}
JO03-93	93.33 (75.24)^{bc}	40.000 (38.855) ^{b}	60.000 (51.145) ^{g}	1:0.67	35.57 (6.05) ^{bc}	36.40 (6.12) ^{bc}	83.33 (66.84) ^{cd}	22.22 (27.87) ^{b}
Kent	89.67 (71.27) ^{abc}	54.762 (47.738) ^{e}	45.238 (42.262) ^{d}	1:1.21	34.54 (5.96) ^{bc}	35.71 (6.06) ^{cd}	83.02 (65.71) ^{a}	40.00 (39.19) ^{a}
OS-6	93.33 (75.24) ^{bc}	66.667 (54.782) ^{h}	33.333 (35.218) ^{a}	1:2.0	33.99 (5.91) ^{c}	34.48 (5.96) ^{d}	78.33 (62.29) ^{abc}	31.11 (33.87) ^{ab}
UPO-212	86.11 (68.23) ^{a}	61.111 (51.490) ^{g}	38.889 (38.510) ^{b}	1:1.57	34.61 (5.97) ^{bc}	35.76 (6.06) ^{cd}	94.43 (76.93) ^{e}	37.78 (37.91) ^{a}
SEm±	2.25	3.25	3.51	-	0.05	0.04	3.30	2.53
CD at 5%	6.75	9.77	10.53	-	0.14	0.12	7.00	5.37

#=Figures in parentheses are arc sin transformed value

As per DMRT test (p<0.05) means within column followed by similar alphabets are non-significant

Table 4: Impact of fodder oat genotypes on *S. frugiperda* pupal and adult morphometrics

Fodder oat genotypes	Pupal morphometrics (mm)*				Adult morphometrics (mm)*			
	Male		Female		Male		Female	
	Length	Width	Length	Width	Body length	Wing expansion	Body length	Wing expansion
JO-1	13.906 (3.859) ^{b}	3.970 (2.229) ^{d}	14.541 (3.942) ^{bcd}	4.277 (2.297) ^{b}	11.95 (3.60) ^{de}	27.57 (5.34) ^{c}	12.66 (3.70) ^{c}	28.10 (5.39) ^{b}
JO-2	12.417 (3.661) ^{b}	4.225 (2.285) ^{cd}	14.291 (3.910) ^{cd}	4.328 (2.308) ^{b}	11.86 (3.58) ^{e}	28.97 (5.47) ^{abc}	12.93 (3.73) ^{c}	29.04 (5.48) ^{ab}
JO-5	11.917 (3.593) ^{b}	4.305 (2.302) ^{cd}	13.922 (3.862) ^{d}	4.439 (2.331) ^{b}	12.40 (3.66) ^{cde}	27.80 (5.37) ^{c}	12.73 (3.71) ^{c}	28.33 (5.42) ^{b}
JO03-91	11.750 (3.570) ^{b}	4.284 (2.298) ^{cd}	14.464 (3.932) ^{bcd}	4.379 (2.317) ^{b}	12.54 (3.68) ^{cde}	27.97 (5.38) ^{ac}	13.91 (3.86) ^{b}	28.39 (5.42) ^{b}
JO03-93	12.443 (3.666) ^{b}	4.398 (2.323) ^{cd}	15.205 (4.025) ^{abc}	5.031 (2.456) ^{a}	13.02 (3.74) ^{bcd}	28.08 (5.39) ^{abc}	13.84 (3.85) ^{b}	29.36 (5.51) ^{a}
Kent	12.167 (3.628) ^{b}	5.149 (2.479) ^{cd}	15.426 (4.053) ^{ab}	5.499 (2.549) ^{a}	13.25 (3.77) ^{abc}	29.39 (5.51) ^{a}	14.35 (3.92) ^{ab}	29.76 (5.55) ^{a}
OS-6	11.833 (3.582) ^{b}	4.755 (2.398) ^{bc}	5.086 (2.467) ^{a}	1:0.32	13.67 (3.83) ^{ab}	27.82 (5.37) ^{c}	14.39 (3.92) ^{ab}	28.09(5.39) ^{b}
UPO-212	12.443 (3.666) ^{a}	5.411(2.532) ^{a}	15.761 (4.094) ^{a}	5.665 (2.581) ^{a}	14.15 (3.89) ^{a}	29.33 (5.51) ^{ab}	14.95 (3.99) ^{a}	29.65 (5.54) ^{a}
SEm±	0.055	0.040	0.038	0.041	0.05	0.04	0.04	0.03
CD at 5%	0.165	0.120	0.114	0.123	0.14	0.12	0.11	0.08

*= Figures in parentheses are square root transformed value

As per DMRT test (p<0.05) mean within column followed by similar alphabets are non-significant

Nutritional indices

The Consumption index (CI) is the amount of food ingested per mg body weight of the insect per day, while Relative growth rate (RGR) indicates biomass gained by the insect in relation to its weight for overall larval duration. The CI and RGR ranged from 0.042 (JO-5) to 0.096 (OS-6) and 0.021 (JO-2) to 0.035 (OS-6), respectively (Table 5).

The Approximate digestibility (AD) is the percentage of the digested food that is effectively assimilated by insect, whereas Efficiency of conversion of ingested food (ECI) in the percentage of ingested food that is transferred into biomass and Efficiency of conversion of digested food (ECD) is the percentage of digested food that is converted into biomass (Sharma, 1998) [27]. In the present study the AD, ECI and ECD for *S. frugiperda* larvae ranged from 43.32 (JO-2) to 65.46 (OS-6), 41.08 (JO-2) to 58.44 (JO03-91) and 85.61 (OS-6) to 94.83 (JO-2), respectively. The present findings are in conformity with the findings of Barcelos *et al*., (2018) [3], as they reported that the CI, AD, ECI and ECD were 0.94, 34.8, 4.5 and 29.5, respectively.

Table 5: Impact of fodder oat genotypes on nutritional indices of larvae of *S. frugiperda* (1st to 6th instar)

Fodder oat genotype	Mean consumed leaves (mg/larva)	Mean larval Weight (mg/larva)		Mean faecal weight (mg/larva)	Mean feeding period (days)	Nutritional indices 1st to 6th instar larvae				
		Mean	Gained			CI	RGR	ECI	AD	ECD
JO-1	1806.54	1468.2	926.68	817.65	16.80	0.073	0.031	51.29	54.73	93.70
JO-2	3471.65	2636.9	1426.4	1967.6	19.56	0.067	0.021	41.08	43.32	94.83
JO-5	2583.89	3263.1	1364.4	1105.7	18.76	0.042	0.028	52.80	57.20	92.30
JO03-91	2671.34	3206.7	1561.3	942.3	17.34	0.048	0.034	58.44	64.72	90.30
JO03-93	2990.82	3220.2	1658	1185.5	17.11	0.054	0.032	55.43	60.36	91.84
Kent	3530.54	3389.2	1794.4	1458.9	15.43	0.068	0.033	50.82	58.67	86.61
OS-6	2847.97	1878.3	1596.1	983.6	15.83	0.096	0.035	56.04	65.46	85.61
UPO-212	3178.27	3246	1597.9	1332.7	14.93	0.066	0.034	50.27	58.06	86.58
Mean± SD	2885.12± 519.48	2788.59± 684.77	1490.65± 246.48	1224.24± 342.35	16.97± 1.50	0.064± 0.015	0.030± 0.0043	52.02± 4.928	57.82± 6.454	90.22± 3.314

CI = Consumption Index, RGR= Relative Growth Rate, AD= Approximate Digestibility, ECI= Efficiency of conversion of ingested food, ECD= Efficiency of conversion of digested food

Biological indices

The growth index, standardized growth index and fitness index of *S. frugiperda* ranged from JO-1 (4.43) to UPO-212 (6.25), JO-2 (8.25) to UPO-212 (13.83) and JO-2 (501.51) to UPO-212 (826.62) respectively. The male adult index was highest on OS-6 while the female adult index was highest on JO-2. These indices suggest that in the above-mentioned genotypes, the adult moths lived for a longer period of time as compared to the other fodder oat genotypes included in the study. Survival index was maximum on UPO-212 and minimum on JO-2, which indicated that the survival of *S. frugiperda* was higher on highly susceptible and lowest on least susceptible genotypes.

Population growth parameters of *S. frugiperda*

The net productive rate (NRR), intrinsic rate of increase (IRI) and finite rate of increase (FRI) was maximum on OS-6 (371.98, 0.17 and 1.18 respectively) and minimum on JO-5 (40.94, 0.10 and 1.10 respectively). The mean generation time and doubling time which is the duration required to double the population size was found to be highest on JO-2 (37.97 days) and JO-5 (6.90 days), respectively, while the lowest was on OS-6 (34.24 and 4.00 days, respectively). The results are in agreement with the findings of Wang *et al*., (2020) [33] as they also reported higher NRR, IRI, FRI and mean generation time (406.37, 0.0256, 1.283 and 29.21 days respectively) on maize.

Applicability of Dyar's law, Przibram's and Megusar's rule

The instar wise progression in head capsule width (HCW) of *S. frugiperda* larvae reared on highly and least susceptible genotypes was in agreement with Dyar's law, while the progressive increase in body length and body width deviated from the rules proposed by Przibram and Megusar. The present findings revealed that there was no effect of relative susceptibility of fodder oat genotypes on the progressive increase of HCW, BL and BW of *S. frugiperda*. The present findings support the findings of Vashisth and Chandel (2013) [32], as they also claimed that in *S. litura*, the instar wise progressive development in HCW followed Dyar's law, but the body length and width did not support Przibram and Megusar's theory.

Conclusion

The local environmental conditions in which an insect lives have an impact on its growth. Therefore, understanding the biology of an invasive insect species in a particular area is crucial for managing that species there effectively. Life cycle and morphometric parameters of FAW were studied to understand the behavior of the pest, which will ultimately help to design an IPM strategy on oat crop. Among the tested fodder oat genotypes Kent, OS-6 and UPO-212 were found to be highly susceptible, whereas JO-1, JO-2 and JO-5 as least susceptible and JO03-91 and JO03-93 as moderately susceptible to *S. frugiperda*.

References

1. Alemayehu GF, Forsido SF, Tola YB and Amare E. Nutritional and Phytochemical Composition and Associated Health Benefits of Oat (*Avena sativa*) Grains and Oat-Based Fermented Food Products. The Scientific World Journal, 2023, 1-16.
2. Assefa F, Ayalew D. Status and control measures of fall armyworm (*Spodoptera frugiperda*) infestations in maize fields in Ethiopia. Cogent Food & Agriculture. 2019;5(1):1641902.
3. Barcelos LM, Fernandes FO, Lopes C, Emygdio BM, Valgas R, Carvalho Indyra F de, *et al*. Biology and Nutritional indexes of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in saccharine sorghum. Journal of Agricultural Science. 2019;11(4):126-135.
4. Bhusal K, Bhattarai K. A review on fall armyworm (*Spodoptera frugiperda*) and its possible management options in Nepal. Journal of Entomology and Zoology Studies. 2019;7(4):1289-1292.
5. Borigas KGB, Mendes SM, Waquil JM, Fernandes GW. Fitness stage of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on alternative hosts. Bragantia. 2013;72(1):61-70.
6. Bueno RCOF, Carneiro TR, Bueno AF, Pratissoli D, Fernandes OA, Vieira SS. Parasitism capacity of *Telenomusremus* Nixon (Hymenoptera: Scelionidae) on *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) eggs. Brazilian Archives of Biology and Technology. 2010;53:133-139.
7. Devi R, Sood VK, Chaudhary HK, Kumari A, Sharma A. Identification of promising and stable genotypes of oat (*Avena sativa* L.) for green fodder yield under varied climate conditions of north-western Himalayas. Range Management and Agroforestry. 2019;40(1):67-76.
8. Gebretsadik KG, Liu Y, Yin Y, Zhao X, Li X, Chen F, *et al*. Population Growth of Fall Armyworm, *Spodoptera frugiperda* Fed on Cereal and Pulse Host Plants Cultivated in Yunnan Province, China. Plants. 2023;12(4):950.
9. Helen PA, Tamboli ND, Kulkarni SR, More SA,

Kumbhar JS. Biology of fall army worm *Spodoptera frugiperda* (J.E. Smith) on maize under laboratory conditions. Journal of Entomology and Zoology Studies. 2021;9(3):125-127.
10. Igyuve TM, Ojo GOS, Ugbaa M, Ochigbo AE. Fall Army Worm (*Spodoptera frugiperda*): It's Biology, impact and control on maize production in Nigeria. Nigerian Journal of Crop Science. 2018;5(1):70-79.
11. Ihsan M, Nisar M, Nazir N, Zahoor M, Khalil AAK, Ghafoor A, *et al*. Genetic diversity in nutritional composition of oat (*Avena sativa* L.) germplasm reported from Pakistan. Saudi Journal of Biological Sciences. 2022;29:1487-1500.
12. Kalyan D, Mahla MK, Ramesh S, Kalyan RK, Swathi P. Biological parameters of *Spodoptera frugiperda* (J.E. Smith) under laboratory conditions. International Journal of Current Microbiology and Applied Science. 2020;9(5):2972-2979.
13. Khedr MA, AL-Shannaf HM, Mead HM, Shaker Abd EL-A. Comparative study to determine food consumption of cotton leafworm, *Spodoptera littoralis* on some cotton genotypes. Journal of Plant Protection Research. 2015;55(3):312-321.
14. Manjula K, Saheb YP, Sudheer MJ, Rao AR. Studies on biology, feeding habits and natural enemies of fall armyworm, *Spodoptera frugiperda*, a new invasive pest in India. Journal of Entomology and Zoology Studies. 2019;7(6):1245-1250.
15. Marcela MN, Mario VN. Life cycle, morphometry and natural enemies of fall army worm, *Spodoptera frugiperda* (J.S. Smith) on *Zea mays* L. in the Philippines. Journal of International Society for Southeast Asian Agriculture Sciences. 2020;26(2):17-29.
16. Montezano DG, Specht A, Daniel R, Gómez S, Roque - Specht VF, Malaquias JV, *et al*. Biotic potential and reproductive parameters of *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae). Journal of Agricultural Science. 2019;11(13):240-252.
17. Nabity PD, Zangerl AR, Berenbaum MR, Delucia EH. Bioenergy crops *Miscanthus giganteus* and *Panicumvirgatum* reduce growth and survivorship of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Journal of Economic Entomology. 2011;104:459-464.
18. Nagoshi RN, Adamczyk JJ, Meagher J, Gore RL, Jackson R. Using stable isotope analysis to examine fallarmyworm (Lepidoptera: Noctuidae) host strains in a cotton habitat. Journal of Economic Entomology. 2007;100(5):1569-1576.
19. Naik Manja C, Nataraj K, Santhoshakumara GT. Comparative biology of *Spodoptera litura* on vegetable and grain soybean [Glycine max (L.) Merrill]. International Journal of Current Microbiology and Applied Sciences. 2017;6(7):366-371.
20. Narayanamma V, Lavakumar Reddy M, Krishnaiah NV. Fall armyworm: A new invasive pest of maize in India. Indian Farming. 2020;70(4):35-39.
21. Narvekar PF, Mehendale SK, Desai SD, Karmarkar MS, Golvankar GM. Host preference and digestibility indices of *Spodoptera litura* (Fab.) on different host plants under laboratory condition. International Journal of Chemical Studies. 2018;6(6):1657-1661.
22. Pogue GM. A world revision of the genus *Spodoptera* Guenée (Lepidoptera: Noctuidae). Memoirs of the American Entomological Society. 2002;43:1-202.
23. Ramaiah M, Maheswari TU. Biology studies of tobacco caterpillar, *Spodoptera litura* Fabricius. Journal of Entomology and Zoology Studies. 2018;6(5):2284-2289.
24. Sandhya M, Gaikwad DS, Manisha P. A review article on fodder oats (*Avena sativa* L) intercropping with legume crops. International Journal of All Research Education and Scientific Methods. 2020;8(11):726-730.
25. Santos LM dos, Redaelli LR, Diefenbach LMG, Stoffel CF. Fertility and longevity of *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in corn genotypes. Ciência Rural, Santa Maria. 2003;34(2):345-350.
26. Sharanabasappa, Kalleshwaraswamy CM, Maruthi MS, Pavithro HB. Biology of invasive Fall army worm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on maize. Indian Journal of Entomology. 2018;80(3):540-543.
27. Sharma R. Studies on food consumption assimilation and development in *Pieris brassicae* (L.) (Lepidoptera: Pieridae). M.Sc. Thesis, College of Horticulture, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-Solan, 1998, 91.
28. Shull DR, Stewart RL, Paulson GS. Application of Dyar's law to life stages of *Sigaramathesoni* (Heteroptera: Corixidae). Entomological News. 2010;121(5):469-474.
29. Siddhapara R, Patel KM, Patel AG. Biology and morphometrics of fall armyworm *Spodoptera frugiperda* (J.E. Smith) on maize. Indian Journal of Entomology. 2021;83(4):1-3.
30. Silva DM da, Bueno AF, Andrade K, Stecca CS, Neves PMOJ, Neves O. Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on different food sources. Scientia Agricola. 2017;74(1):18-3.
31. Tiwari S, Deole S, Potai A. Investigation on egg hatching percent of fall army worm in different genotypes of maize crop. Journal of Entomology and Zoology Studies. 2020;8(4):2119-2121.
32. Vashisth S, Chandel YS. Morphometrics of *Spodoptera litura* on tomato. Indian Journal of Plant Protection. 2013;41(2):175-177.
33. Wang W, He P, Zhang Y, Liu T, Jing X, Zhang S. The population growth of *Spodoptera frugiperda* on six cash crop species and implications for its occurrence and damage potential in China. State Key Laboratory of Crop Stress Biology for Arid Areas, Northwest A&F University, China. 2020;11(9):639.
34. www.icar-crida.res.in:8080Via Lifetable calculator.
35. Xue M, Pang YH, Wang HT, Li QL, Liu TX. Effects of four host plants on biology and food utilization of the cutworm, *Spodoptera litura*. Journal of Insect Science. 2010;10(22):1-14.