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Nutritional Impact of Diets on Development, Reproduction and Mass Multiplication of Fall Armyworm (Faws), Spodoptera Frugiperda

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Abstract

Problem - Spodoptera frugiperda (fall armyworm) has recently spread across numerous African and Asian countries, posing a significant threat to global agricultural production. **Approach -** This study aimed to evaluate the rearing performance of fall armyworm larvae using five artificial diets and one control (natural diet) to identify a suitable diet for mass multiplication. The diets tested were D1 (chickpea-based), D2 (wheat-based), D3 (soybean-based), D4 (bean-based), D5 (cowpea-based), and D6 (maize leaves as a control). Rearing conditions were maintained at 25 ± 2°C, 65 ± 10% relative humidity, and a 12:12 h light-dark photoperiod. Larval period, pupal period, adult longevity, generation time, fecundity, and net reproductive rate were recorded and compared.**Findings -** Larvae fed on D1 (chickpea-based diet) had a larval period of 16.30 days, a pupal period of 9.10 days, and an adult longevity of 12.46 days. The total generation time was 42.31 days, with a fecundity of 629.90 eggs/female. D1 showed a shorter mean generation time and doubling time compared to the control (D6). The net reproductive rate (R_0) for D1 was 515 offspring/individual, surpassing the control diet. **Conclusion -** The chickpea-based artificial diet (D1) demonstrated superior results for rearing fall armyworms, indicating its effectiveness for mass multiplication in agricultural management strategies.

Keywords: Fall armyworm Spodoptera frugiperda, Mass multiplication, Diets, Life table parameter, Developmental biology.

Introduction

The fall armyworm (FAW), Spodoptera frugiperda (Smith), originates from tropical and subtropical areas of the Americas (Zacarias, 2020). Due to its robust migratory capabilities, it has become a significant agricultural pest across the globe (Sun et al., 2021), with high fecundity (Xie et al., 2021), voracious feeding (Hussain et al., 2021), a wide range of hosts (Chromule et al., 2019; Hussain et al., 2021), and the Brassicaceae family as other hosts (Osdaghi, 2020). The fall armyworm targets maize at various physiological stages, with new larvae preferring more succulent plants for feeding (Nwanze et al., 2021). This pest can cause yield losses of up to 70% (Yan et al., 2022; Idreeset al., 2022). The estimated annual losses range from 8.3 to 20.6 million tons (Chatterjee et al., 2023; Wu et al., 2021).

Chemical control remains the primary method employed against fall armyworms. However, the prolonged use of chemical pesticides poses significant challenges, including environmental pollution, the depletion of predator population, as well as the development of resistance (Zhang et al., 2020) and the emergence of resistance on transgenic varieties of maize against fall armyworm (Li et al., 2022; Ndung et al., 2023). There is a need for integrated pest management approaches for management of the fall armyworm. An eco-friendly technique“sterile insect technology ”(SIT) (Knipling, 1995), which has been extensively utilized against various ranges of agricultural pests and hazards to human health since the 1950s (Klassen, 2005). The Sterile Insect Technique (SIT) has been effectively used to control various lepidopteran insects, including Pectinophora gossypiella (Saunders) and Cydia pomonella (L.), in the United States and Canada (Bloem & Bloem, 2000). A recent study conducted by Jiang, 2022 examined the effect of a proper dose of X-ray radiation on the fall armyworm for sterilization.

Several research studies have been carried out on the biology of S. frugiperda all over the world (Putra and Wulanda, 2021; Megasari et al., 2022; Chen et al., 2023), but the biology of the fall armyworm differs based on various factors like the effect of the biochemical composition of the plant (Chen et al., 2023), geographic location, and bioecology of the insect due to different environmental parameters (Golikhajeh et al., 2017). In this study, the impacts of artificial diets and traditional diet on the biological parameters, survival, and reproduction, which helped in the construction of the age-stage-specific life table of the fall armyworm using a two-sex life table.

Material and methods

Fall armyworm, Spodoptera frugiperda:

The experiment was started with the collection of fall armyworms (FAWs), Spodoptera frugiperda larvae, from the maize field of Lovely Professional University. The species was discovered and validated using morphological characteristics (Higo et al., 2022). For the maintenance of nucleus culture, the larvae were reared on maize leaves until the eclosion of females and oviposition. After hatching of eggs, keep the progeny larvae in a transparent plastic cup (3 cm diameter × 4 cm height; 20–30 insects per plastic cup) and provide a chickpea-based diet (Sagar et al., 2023) for mass multiplication of the colony of fall armyworm. We reared both the matured and immature stages of insects under in vivo conditions (25 ± 2 °C, 65 ± 10 %, and a 12:12 h L:D photoperiod). Before starting the experiment, five generations of fall armyworms had been reared on chickpea-based diets, and hence this diet is effective for the mass multiplication process of FAWs.

Composition and Preparation of diet

In this study, we decided on the five different artificial diets and maize leaves to fulfill this research. D1: chickpea-based artificial diet described by Sagar et al., (2023); D2: wheat-bran-based artificial diet given by Ge et al., (2022); D3: soybean-based artificial diet described by Lekha et al., (2020); D4: bean-based diet described by (Ashok et al., (2021); D5: cowpea-based artificial diets described by Lekhaet al., (2020); and D6: fresh maize leaves as a control (Table. 1)

Table: 1Composition of different artificial diets for FAW

Fraction	Ingredients	D1	D2	D3	D4	D5	D6
Part-I	Bengal gram Cicer arietinum var. kabuli flour (gm)	90.00	-	-	-	-	Fresh maize leaves
	Bean flour (gm)	-	-	-	88.4	-	
	Wheat bran (gm)	-	260	-	-	-	
	Soybean flour (gm)	-	-	100	-	-	
	Cow pea flour (gm)	-	-	-	-	100	
	Yeast extract (gm)	11.00	-	10	22.7	10	
	Casein fat free (gm)	5.00	40	-	-	-	
	L-ascorbic acid (gm)	3.00	3	3.6	2.5	3.6	
	Methyl-p-hydroxy benzoate (gm)	2.00	-	2	2	2	
	Sorbic acid (gm)	1.00	3	1	1.3	1	
	Cholesterol (gm)	0.2	-	-	-	-	
	Streptomycin sulphate (gm)	0.4	-	-	0.4	-	
	Aureofungin 46.15% (gm)	-	-	-	0.5	-	
	Formaldehyde solution 41% (ml)	1.0	2	5	2	5	
	Glacial acetic acid (ml)	-	4	-	-	-	
	Multivitamin and multimineral drops (ml)	1.0	-	7	5	7	
	Sucrose (gm)	-	-	-	35.3	-	
	Methyl parabean (gm)	-		-	2	-	
Part-II	**Vitamine E USP 400mg (Evion) (capsules)**	**2**	1	-	2	-	

	Double distilled water (ml)	**600**	1500	800	400	800	
	Agar-agar powder (gm)	**16.0**	20	12	12.6	12	

Experimental assay:

Effect of artificial diets on the different stages of fall armyworm (FAWs) in a lifecycle:

For this study, we used a fifth-generation-old culture of FAWs, reared under laboratory conditions (25 ± 2 °C, 65 ± 10%, and a 12:12 h L:D photoperiod). Every diet and maize leaf consisted of 30 individuals with FAWs. Before starting the experiment, we collected egg masses of FAWs from the reared colony and observed them until hatching. Once hatching was done, we placed the larvae in a transparent plastic cup (50 ml) with an appropriate diet of maize leaves. To avoid any kind of human operation or mechanical damage, we placed 1-3 larvae in each plastic cup, and from that, we selected one larva randomly from a cup until the third instar. After that, we separated one larva placed in each plastic cup to avoid cannibalism, provided them with different diets and maize leaves for feeding up to the emergence of adults, and tested the morphometric observation of the respective stages of FAWs. To avoid the impact of food freshness on the study, artificial diets were changed every 1-2 days, and fresh maize leaves were provided daily. Observations were documented, like the incubation period, larval period in different instars, pupation period, adult longevity, sex ratio, etc. We observed pupae for survival daily up to eclosion or death.

Adult development and fecundity

The pupae were separated according to male and female and then released one healthy pair of FAWs in a plastic box (1000 ml), covered with muslin cloth for proper ventilation, and stripes of black paper were placed inside the box for egg laying. A 10% v/v honey solution was provided with the help of cotton swabs on the side wall of the box as food and water to a pair of FAWs (Table 2). The cotton swabs and black paper were changed daily, and the box was also replaced if eggs were laid on the side wall. The observations were recorded on different parameters like pre-oviposition period, daily fecundity, oviposition period, incubation period, male and female longevity, and male and female life span (days). The experiment was designed using a completely randomized approach, with each larva serving as a replication. Dead and malformed insect stages of FAWs were preserved in 70% ethanol.

Table: 2Particulars for the adult fall armyworm

Sr.no	**Particulars**	**Quantity**
1	Honey (ml)	20
2	L-ascorbic acid (gm)	1.2
3	Methyl-p-hydroxy benzoate (gm)	0.2
4	Vitamin E USP 400 mg (capsule)	2
5	Streptomycin sulphate (gm)	0.2
6	Multivitamin and multimineral drops (ml)	1
7	Double distilled water (ml)	200

Sagar et al., 2023

Life table parameters

The study of the life table of FAWs utilized various parameters, including lx, fx, mx, and lxmx. Demographic parameters such as the net reproductive rate (R_0), intrinsic rate of natural increase (r), generation time (T), and finite rate of increase (λ) were also examined (Chi, 1988).

$$\mathrm{lx} = \sum_{j=1}^{m} S_{xj}$$

$$\mathrm{mx} = \frac{\sum_{j=1}^{m} S_{xj} f_{xj}}{\sum_{j=1}^{m} S_{xj}}$$

$$\sum_{x=0}^{\infty} l_x\, m_x\, e^{-r(x+1)} = 1$$

$$R_0 = \sum_{x=0}^{\infty} l_x\, m_x$$

$$T = \frac{l_n R_0}{r}$$

$$\lambda = e^r$$

$$e_{xj} = \sum_{i=x}^{\infty} \sum_{y=j}^{k} \mathrm{Siy}$$

In this context, x represents the time interval in days, m denotes the number of stages, and Sxj is the survival rate of the fall armyworm from egg development to x days old at developmental stage j. The population age-specific survival rate, lx, indicates the survival rate from egg to x days old. Age-specific fecundity at age x is denoted as fx, while mx refers to the average population fecundity from egg to x days old. The product of lx and mx gives lxmx, the population age-specific maternity, where life expectancy (exj) shows the expectable period that an individual of age 'x' and stage 'j' will survive.

Statistical Analysis

To analyze the effects of various diets and maize leaves on development and reproductive parameters, a one-way analysis of variance (ANOVA) was used, followed by Duncan's LSD post hoc test. We investigated the interactions of diet and sex on the development and pupal mass of FAWs, considering diet and sex as fixed effects. For the analyses, we used IBM SPSS 22.0 with a ($p < 0.05$) significance level. The life tables (lx, fx, mx, and lxmx) and demographic characteristics (R_0, T, r, λ, and Dt) were examined using TWOSEX-MSChart (Chi and Su, 2006; Chi, 2020; He et al., 2021). To accurately estimate the mean and standard error among the demographic parameters of FAWs fed different diets, we conducted a paired bootstrap test with 100,000 replications using TWOSEX-MSChart (Chi, 2020).

Result and Discussion

Developmental Period and Reproductive Parameters

The fall armyworm, Spodoptera frugiperda, completed its lifecycle on all artificial diets and maize leaves. The diets significantly influenced the developmental duration of FAWs at each stage of life, except the egg stage (Table 3). The developmental duration of the first and second instar stages exhibited no statistically significant differences across all diets ($P > 0.05$). Where statistically significant differences were shown in (third instar larvae: $F_{5,165} = 10.11$, $p = 0.002$; fourth instar larvae: $F_{5,163} = 12.134$, $p < 0.05$; fifth instar larvae: $F_{5,161} = 18.128$, $p < 0.05$; sixth instar larvae: $F_{5,153} = 17.761$, $p < 0.05$), the larval period ($F_{5,153} = 55.248$, $p = 0.000$), pupal period ($F_{5,125} = 2.656$, $p = 0.000$), egg-pupa stage ($F_{5,125} = 34.512$, $p = 0.000$), adult longevity ($F_{5,125} = 2.394$, $p = 0.003$), and total life span ($F_{5,125} = 39.829$, $p = 0.002$) among the artificial and natural diet treatments. Fall armyworms fed on diet D1 had the shortest larval period (16.30 days), followed by diet D3 (17.45 days), which showed a significantly shorter larval period than the other diets. The larval periods in diet D2 (19.35 days), D6 (maize leaves) (19.78 days), diet D5 (19.95 days), and diet D4 (21.09 days) showed no significant difference with a longer period than the fall armyworm fed on other diets. The pre-pupal period showed no significant difference between all the treatments ($p > 0.05$). The pupal period of diet D1 was significantly shorter (9.10 days) than the other diets and D6 (maize leaves), where statistically significant differences were observed between the diet D1 and D6 (maize leaves). The adult longevity of fall armyworm was the longest (12.46 days) in diet D1-fed FAWs, followed by diet D2 (10.93 days) and diet D4 (10.10 days). Similar findings were recorded by Sagar et al., (2023) on chickpea-based diets and Pinto et al., (2019) on the wheat-bran-based diet. The adult stage of FAW fed on maize leaves was observed to be the shortest (9.89 days). The fall armyworm fed on diet D1 showed a statistically shortest life span (42.31 days), compared to the longest life span (46.94 days) in diet D4 with respect to other diets and D6 (maize leaves).Jin et al.,(2020) reported that the nutritive value of chickpea such as carbohydrates, protein, minerals and fat is directly responsible for the larval period, pupal period, larval survival rate, pupal survival rate, and biological performance of insects.

The pre-oviposition period of fall armyworm is shorter than the oviposition period, where diet D1 showed a longer pre-oviposition, oviposition, and post-oviposition period as compared to other diets and maize leaves, and a shorter period was observed in diet D6. A similar result was shown by Navasero and Navasero, (2020), who concluded that a longer pre-oviposition period in S. frugiperda suggests a longer sexual maturation period for females, where the fecundity of females was 629.90 per female recorded in diet D1. As per Wang et al., (2019),fall armyworms were reared on wheat bran-based artificial diets and achieved the highest egg-laying capacity of 452 and 836 eggs per female. The biotic potential of fall armyworm was estimated at (2.10×10^{24}) in diet D1 followed by diet D3 (8.25×10^{22}). Significant interaction (diet*sex) was reported in the pupal period (F_5=10.229, $p < 0.001$), adult stage ($F_5 = 2.901$, $p < 0.05$), and total generation ($F_5 = 3.346$, $p < 0.05$).

Table: 3. Mean duration and reproductive performance (± SE) of developmental stages of fall armyworm on different artificial diets and natural diet (maize leaves)

Parameter (Duration in days)	Biological parameter						F value	P value
	D1	D2	D3	D4	D5	Maize leaves		
Egg	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	-	-
1st instar larva	2.80±0.20^{b}	3.00±0.26^{ab}	2.85±0.18^{b}	3.30±0.23^{ab}	3.03±0.19^{ab}	3.55±0.18^{a}	3.13	0.111^{NS}
2nd instar larva	2.00±0.30^{a}	2.10±0.23^{a}	2.25±0.23^{a}	2.40±0.31^{a}	2.68±0.17^{a}	2.70±0.37^{a}	8.25	0.354^{NS}
3rd instar larva	2.70±0.25^{b}	3.00±0.22^{b}	2.75±0.17^{b}	3.77±0.24^{a}	2.93±0.16^{b}	2.58±0.16^{b}	10.11	0.002**
4th instar larva	2.45±0.19^{c}	3.30±0.31^{ab}	2.75±0.19^{bc}	3.75±0.30^{a}	3.08±0.24^{abc}	2.90±0.22^{bc}	12.13	0.010**
5th instar larva	2.45±0.20^{c}	3.25±0.19^{ab}	2.70±0.23^{bc}	2.88±0.24^{abc}	3.33±0.24^{ab}	3.45±0.25^{b}	18.12	0.017*
6th instar	3.90±0.16	4.70±0.33	4.15±0.20	5.00±0.32^{a}	4.93±0.26^{ab}	4.60±0.18	17.7	0.01

larva	^{c}	^{ab}	^{bc}			^{abc}	6	9*
Larval stage	16.30±0.48^{b}	19.35±0.81^{a}	17.45±0.56^{b}	21.09±0.70^{a}	19.95±0.51^{a}	19.78±0.56^{a}	55.24	0.000***
Pre-pupal	1.45±0.11^{a}	1.50±0.14^{a}	1.55±0.13^{a}	1.50±0.13^{a}	1.30±0.10^{a}	1.65±0.14^{a}	4.26	0.575^{NS}
Pupa	9.10±0.28^{c}	10.25±0.16^{b}	10.10±0.31^{b}	10.50±0.23^{ab}	9.95±0.36^{bc}	11.33±0.32^{a}	2.65	0.000***
Pre-adult period	29.85±0.68^{c}	34.10±0.80^{ab}	32.10±0.76^{b}	36.14±0.80^{a}	34.20±0.60^{ab}	35.75±0.36^{a}	34.51	0.000***
Adult longevity	12.46±0.31^{a}	10.93±0.58^{b}	10.10±0.44^{b}	10.80±0.57^{b}	10.04±0.55^{b}	9.89±0.20^{b}	2.39	0.003**
Total generation	42.31±0.63^{b}	45.03±1.25^{a}	42.20±0.77^{b}	46.94±1.06^{a}	44.24±0.91^{ab}	45.64±0.39^{a}	39.82	0.002**
Pre-oviposition period	3.28±0.26^{a}	2.90±0.17^{ab}	2.90±0.18^{ab}	3.15±0.21^{a}	3.00±0.21^{a}	2.34±0.11^{b}	2.75	0.028*
Oviposition period	3.78±0.21^{a}	3.60±0.24^{a}	3.13±0.29^{ab}	2.65±0.26^{b}	3.30±0.18^{ab}	3.33±0.26^{ab}	2.61	0.034*
Post-oviposition period(day)	5.40±0.23^{a}	4.43±0.28^{bc}	4.07±0.19^{c}	5.00±0.25^{ab}	3.74±0.28^{c}	4.22±0.22^{c}	6.53	0.000***
Fecundity per female(n)	629.90±37.04^{a}	571.00±61.16^{a}	569.90±31.83^{a}	396.90±50.36^{b}	502.00±59.92^{ab}	558.30±35.49^{a}	2.86	0.023*
Biotic potential	2.10×10^{24}	3.61×10^{21}	8.25×10^{22}	4.25×10^{18}	1.01×10^{22}	6.11×10^{18}	-	-

Values in the same row followed by different lowercase letters indicate significant differences between different diets (one-way ANOVA, Duncan; $p < 0.05$).

Survival Rate, Fecundity and Life Expectancy

The age-stage survival rate (sxj) of Spodoptera frugiperda individuals was significantly influenced by artificial diets and maize leaves (Figure 1). The results revealed that the larval survival rate of diet D1 showed a significant difference ($F_{5,60} = 6.781$, $p < 0.05$) with other diets and D6 (maize leaves), whereas other diets showed no difference between them ($p > 0.05$). The larval survival rate of diet D4 (67.84%) was lower, with a statistically significant difference from diet D1 (98.84%), where there was no statistically significant difference between the remaining diets. The survival rate of pupae was significantly difference between diet D1 and other diets ($F_{5,60}$ = 3.498, $p < 0.05$). The adult deformity rate was statistically significant between all the diets and maize leaves ($F_{5,60}$ = 9.946, $p = 0.002$). The highest percentage of adult deformity rate was observed in the diet D4 (8.45%), followed by diets D2, D3 and D5 (Table 4).

Table: 4 Larval, Pupal survival rate and adult deformity rate of FAWs (*Spodoptera frugiperda*) fed on different artificial diets and natural diet(maize leaves)

Parameters	D1	D2	D3	D4	D5	D6
Larval survival rate (%)	98.84±1.75^{ab}	92.54±2.01^{a}	93.61±1.88^{a}	88.35±5.06^{a}	90.80±2.04^{a}	89.88±2.11^{a}
Pupal survival rate (%)	81.24±6.22^{b}	66.00±9.18^{a}	69.88±8.98^{a}	67.84±8.23^{a}	70.24±8.61^{a}	69.44±8.78^{a}
Adult deformity rate(%)	1.52±0.53^{c}	5.87±1.98^{b}	5.44±1.79^{b}	8.45±2.86^{a}	5.05±1.83^{b}	4.23±1.74^{bc}

Values in the same row followed by different lowercase letters indicate significant differences between different diets (one-way ANOVA, Dunkun; $p < 0.05$).

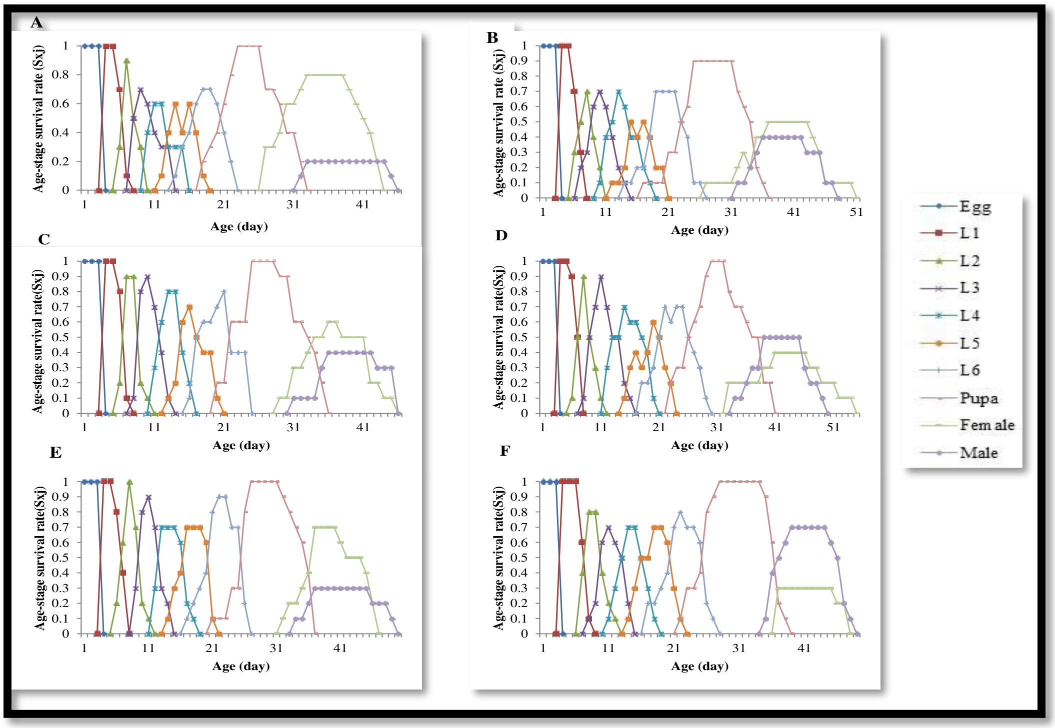

Figure 1 Age-stage survival rate (sxj) of *Spodoptera frugiperda* individuals fed different diets. (A): D1; (B): D2; (C): D3; (D): D4; (E): D5; (F): (D6)Maize leaves

The highest age-specific fecundity (fx) of female adults was observed in individuals fed on diets D1, D2, D3, D4, D5, and D6 (maize leaves), with values of 248, 170, 229, 165, 240, and 212, respectively. The age-specific fecundity (mx) and age-specific maternity (lxmx) curves showed that peak oviposition occurred in the order of diets

D5 > D3 > D1 > D2 >D6 (maize leaves)> D4. The maximum mx values for FAW groups fed on diets D1, D2, D3, D4, D5, and D6 (maize leaves) were recorded on days 29, 35, 33, 32, 36, and 37, respectively, with lxmx peaking on the same days (Figure 2). The age-stage-specific life expectancy (exj) curve indicated that the shortest life expectancy was observed with diet D1, while the longest life expectancy was seen with diet D4, followed by the D2 diet (Figure 3).

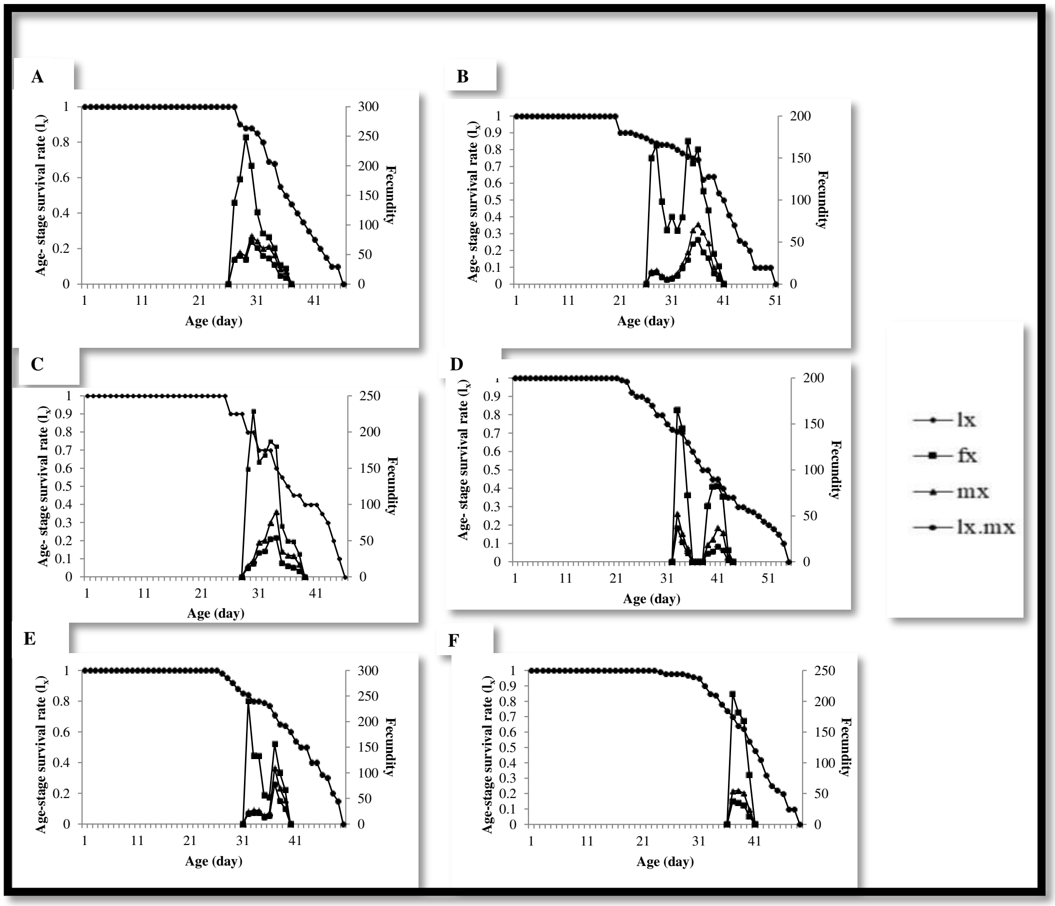

Figure 2Age-specific survival rate (lx), age-specific fecundity of female adults (fx), age-specific fecundity (mx), and age-specific maternity (lxmx) of *Spodoptera frugiperda* individuals fed different diets. (A): D1; (B): D2; (C): D3; (D): D4; (E): D5; (F): D6 (Maize leaves)

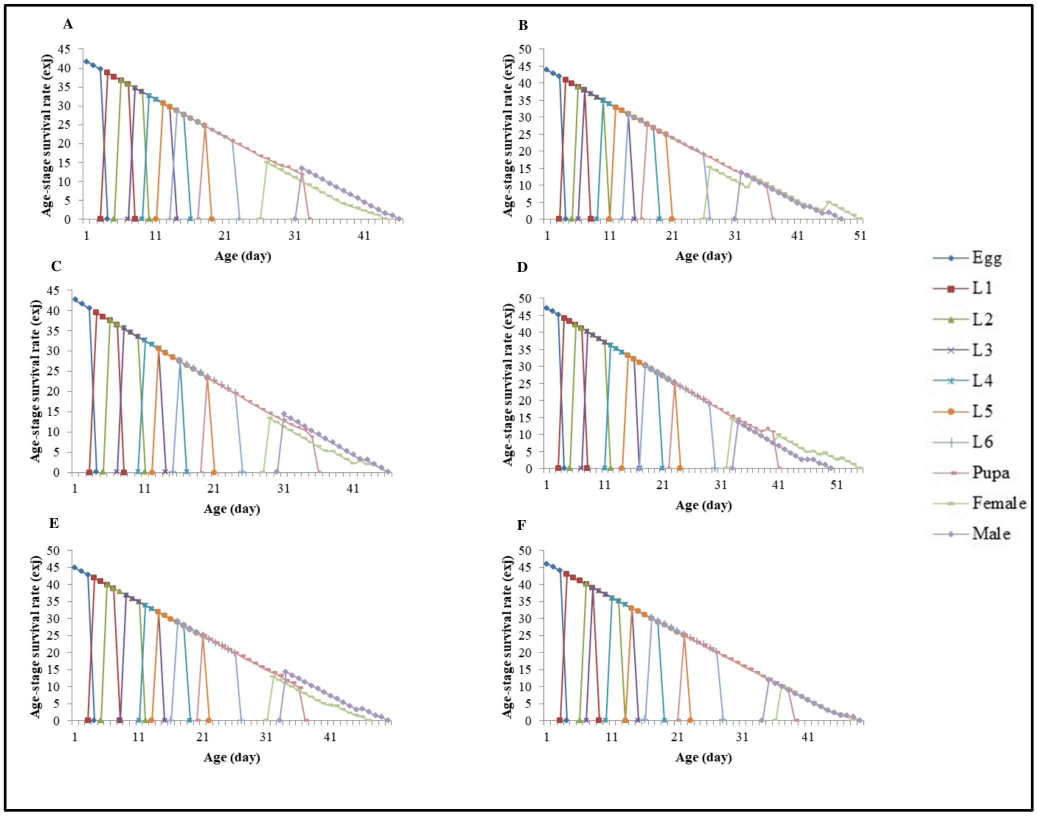

Figure 3 Age-stage specific life expectancy (exj) of *Spodoptera frugiperda* individuals fed different diets. (A): D1; (B): D2; (C): D3; (D): D4; (E): D5; (F): D6 (Maize leaves)

Figure 3 Age-stage specific life expectancy (exj) of *Spodoptera frugiperda* individuals fed different diets. (A): D1; (B): D2; (C): D3; (D): D4; (E): D5; (F): D6 (Maize leaves)

Life Table Parameters

The average generation time (T) of S. frugiperda on five maize lines and artificial diets (between 20.1 and 46.5 d) discovered by Rosa et al., (2012) and Pinto et al., (2019) observation of the current study was similar to this. Net reproduction rate (R_0), intrinsic rate of returns (rm), and finite rate of increase (λ) values were different from those found in two artificial diets by Pinto et al., (2019) (measurements of 755.4, 0.235, and 1.265 and 920.8, 0.236, and 1.266, respectively). The net reproduction rate (R_0) was more than 1, meaning that each female created more than one female, it was feasible to notice that the population expanded and doubled in size (Dt) in around 3.38 days based on the parameters of the fertility life table. The finite increase rate (λ) shows that the population's proportion of females climbed by more than 1.22 times per unit of time, while the intrinsic growth rate (rm) was positive (Table 5).

Table: 5 Life table parameters (mean± SE) of Spodoptera frugiperda individuals fed different diets and maize leaves.

	D1	D2	D3	D4	D5	Maize leaves
Net Reproductive rate R_0 (offspring/individuals)	515±78.81^{a}	375.5±98.08^{abc}	410.2±105.09^{abc}	206.1±71.99^{abc}	340.3±79.28^{ab}	183.2±85.81^{b}
Mean generation time T(d)	30.48±0.73^{a}	33.81±1.62^{bc}	36.03±0.87^{b}	36.44±1.91^{bcd}	36.03±0.87^{c}	38.17±0.29^{d}
Intrinsic rate of natural increase $r(d^{-1})$	0.20±0.0007^{a}	0.17±0.0012^{bcd}	0.18±0.0012^{abd}	0.14±0.0014^{cd}	0.16±0.0007^{de}	0.13±0.0013^{e}
Finite rate of increase $\lambda(d^{-1})$	1.22±0.008^{a}	1.19±0.0014^{bcd}	1.20±0.0012^{abd}	1.16±0.0016^{cd}	1.18±0.0008^{de}	1.14±0.0015^{e}
Doubling time (DT)	3.38±0.12^{a}	3.95±0.29^{abcd}	3.80±0.24^{abc}	4.74±0.60^{bcd}	4.28±0.21^{cd}	5.07±0.57^{d}

Values in the same row followed by different lowercase letters indicate significant differences between different diets (one way ANOVA, Duncan; $p < 0.05$).

Conclusion

Spodoptera frugiperda (FAW), an increasingly significant invasive pest in various countries, necessitates the development of environmentally sustainable management strategies. To support this effort, we have formulated an economical and effective chickpea-based artificial diet D1that facilitates the complete development of FAWs, ensuring high survival rates and fecundity. This novel diet can greatly enhance the mass rearing of FAWs, which is essential for implementing sterile insect techniques (SIT) or producing viral pesticides to control this pest.

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