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Biology and host preference studies of Spodoptera frugiperda (Smith) (Lepidoptera: Noctuidae) in Ethiopia

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ABSTRACT: The fall armyworm (FAW), *Spodoptera frugiperda*, was first reported on the African continent in early 2016 and reported from Ethiopia in early 2017. The host preference and its biology are not known in Ethiopia. Therefore, the current study was aimed at studying the biology and host preferences of FAW. The experiment was carried out in the greenhouse and wire-house of Ambo Agricultural Research Center from July 2021 to October 2021. The biology of FAW was studied using maize, sorghum, chickpeas, barley, and wheat. The experiments were conducted in the average rearing room temperature of 25.5°C to 37.4°C and relative humidity of 35.33% to 45.46%. Data on egg incubation period, pre-pupal, pupal, egg to adult period, pupal weight, sex ratio, and cannibalism percentage were collected for the biology study. The egg incubation period was between 5 and 8 days. The larval developmental period completed in 14 to 19 days, while pupal stage needed 8 to 9 days. FAW females lay 32-122 eggs in their lifetime. The oviposition period was 2 to 3 days. FAW life cycle ranged from 31 to 38 days at the specified temperature and relative humidity. In terms of the sex ratio of FAW, there was no difference between the tested crops. However, significant ($P<0.05$) variation was observed with respect to larval cannibalism when reared on different crops. The host preference study was carried out using choice and no-choice experiments on 23 different crops. Data on preferences for oviposition by adult females and for larval feeding were collected. Compared to the other studied host crops, it was discovered that maize, sorghum, swiss chard, teff, elephant grass, and cabbage were the most preferred hosts for larval development and egg laying. The adult female laid eggs on faba bean, soya bean, haricot bean, garlic, and mustard plants, but the eggs did not hatch into larvae. These findings have important implications for understanding the FAW survival, development, and host preference, as well as knowing the best time to plan its effective management.

Keywords/ phrases: Biology, host preference, oviposition, *Spodoptera frugiperda*

INTRODUCTION

Fall armyworm is native to tropical and subtropical regions of the Americas and was reported for the first time on the African continent in 2016, in Nigeria (Goergen *et al*. 2016) and distributed in 47 African countries (Day *et al*. 2017, Prasanna *et al*. (2018) and Birhanu *et al*. (2019). In Ethiopia, it was first reported at Bench Maji Zone of Southern Ethiopia in 2017 (Abrahams *et al*., 2017; Wu *et al*., 2019).

More than 100 plant species, including maize, sorghum, rice, soybean, cotton, wheat, and sugarcane were reported as severely damaged by FAW (CABI, 2017). However, recent studies confirmed that a total of 353 plant species are hosts of FAW (Kenis*et al*., 2022). FAW poses a serious challenge to the food and nutrition security and livelihoods of millions of farming households in sub-Saharan Africa due to its capacity to spread quickly and cause extensive damage across multiple crops (Baudron *et al*., 2019).

In maize, FAW attacks all the crop stages from seedling to ear development. It causes leaf defoliation, whorl, and ear damage; reduce grain quality and overall yield (Anyanda *et al*., 2022). The studies conducted in 12 maize-producing countries showed that, without control, FAW can result in maize production losses ranging from 4.1 to 17.7 million tonnes, or an estimated loss of US$1088 to US$4661 million annually (Rwomushana *et al*., 2018). Even though the maize yield loss due to FAW in Ethiopia is 36% (Abro *et al*., 2021), in Kenya (De Groote *et al*., 2020) in Zimbabwe (Baudron *et al*. 2019), Ghana (Rwomushana *et al*., 2018) and Zambia

(Rwomushana *et al*., 2018) 37%, 11.57%, 26.6%, 35% yield loss were recorded, respectively.

Therefore, to develop a sustainable management option for this notorious pest, understanding the host preference and its biology in the specific country is important. However, the host preference and its biology are not well known in Ethiopia. Therefore, the current study was targeted at studying the biology and host preferences studies of FAW in Ethiopia.

MATERIALS AND METHODS

Description of the study area

The biology and host preference experiments were carried out at the Ambo Agricultural Research Center (AmARC), which is located at 38°07′ E and 8°57′N and an elevation of 2225m.a.s.l. The area experienced bimodal rainfall, with a mean annual precipitation of 1115 mm. The mean maximum and minimum temperatures of the area are 25.4°C and 11.7°C, respectively.

Mass rearing of FAW

FAW larvae were collected from infested maize fields in Ambo and mass-reared at the AmARC greenhouse inside a rearing cage (0.50 cm width by 1-meter height) being fed on maize seedlings grown in pots according to Tiwari (2022) procedures. The third instar larvae were used for host range studies, while 5 to 8 days old eggs of the second generation were used for FAW biology studies.

Biology study of FAW

Five crops, viz. maize, sorghum, chickpea, wheat, and barley, were used for the biology study of FAW. FAW was reared in a rearing cage measuring 1 meter by 1 meter by 1.5 meters in length, width, and height, respectively. The study was conducted in a greenhouse at the AmARC in an average rearing room temperature of 25.5°C to 37.4°C and relative humidity of 35.33% to 45.46%. The experiment was designed in a randomized complete block design with four replications. The host crop plants were grown in a pot with a diameter of 20cm. The pot was then filled with soil (1% sand, 1% compost, and 2% soil) up to 15 cm from the top edge. Five to 10 seeds of each crop were sown in the pot. Data collection started at the four to six fully developed leaf stages. For data collection, healthy plants of similar size were chosen and tagged. Dead and damaged foliage were counted and checked for the existence of other insect pests and natural enemies before disposal. Plant leaves meant for larval feed were cleaned and disinfected with 1% sodium hypochlorite before being given to the insects. Prior to starting the experiment, all test plants were given 24 hours to acclimate to greenhouse conditions. Then, 10 pairs of pupae were introduced into each pot. A male pupa was distinguished from a female pupa by having a shorter abdomen and a larger head, while a female pupa had a longer abdomen with an ovipositor. Positions of genital and anal openings on the terminal segments were also the other morphological characters used for identification as described by Babu *et al*. (2019) and Prasanna *et al*. (2018).

Data collection

Daily temperature and relative humidity were recorded until the end of the experiment. To record the time of egg hatching, all pots were checked twice a day: in the morning at 9:30 a.m. and in the afternoon at 3:30 p.m. After egg hatching, the total period of the larval developmental stage was recorded. The pre-pupal stage, which is the non-feeding stage between the larval and pupal stages, was collected from the shoots of the five crop plants to figure out the pupal development period. The pre-pupae collections were made through destructive sampling. The pre-pupa was separately kept in a small transparent plastic box (15 cm diameter) with moistened soil and covered with a white mosquito net. Pupal weight (g) 24 hours after pupation, sex ratio, and survival (%) were recorded. Daily observation was made until adult emergence. Days from pupa to adult emergence were also recorded. The number of newly emerged adults was recorded and transferred into their separate crop plants in the pot. Adult longevity was observed and recorded twice a day.

Feed suitability test

The FAW feed suitability experiment was conducted using starved (but water-satiated) 2 third instar larvae under a growth chamber having 25 ± 2°C temperature, 60 ± 10% relative humidity, and a photoperiod of 12:12 hours light-to-day ration. The experiment was laid down in a completely randomized design with 3 replications in the small buckets. To introduce into the selected host crops that had been prepared in the form of chopped stems and leaves, ten FAW third instar larvae of the same weight were mass-reared and starved for 2 h. The feed and larvae were weighed daily on a sensitive balance and the remaining feed and faces were removed and stored separately. Then, up until the sixth instar stage, the initial weight (mg), final weight (mg), amount of feed consumed (mg), amount of feces produced (mg), and feeding interval (days) were recorded. The amount of food consumed by the larvae was calculated using the following formula (Khan and Saxena 1985).

$$\text{Food consumed} = \frac{W1\,(C1 - C2)}{C1 + W2 - W1}$$

where W1 is the initial weight of the treated larva, W2 is the final weight, C1 is the initial weight of the control larva, and C2 is the final weight.

Whereas, the mean cannibalism percentage of FAW was calculated for each larval instar stage by dividing the number of larvae cannibalized by the number of larvae that were initially present.

$$Cannibalism\% = \frac{Hatched - No\ of\ Pupa}{Hatched} \times 100$$

Host Preference Study of FAW

Twenty-three crop plants (Table 1) were used for a choice and no-choice study conducted in the greenhouse and wirehouse for the oviposition and feeding preference studies of FAW. The plants were grown in pots each having a diameter of 20 cm, which were filled with a soil mix of 4 kg (The composition of black soil, compost, and sand at a proportion of 2:1:1) and watered at three days intervals. Five seeds were planted per pot. Five plants with 4 to 6 fully developed leaves were utilized in the trials.

The free-choice study was carried out in screened cages measuring 3 m long, 3 m wide, and 2.5 m high. The no-choice study was done inside individual cages having a size of 1m × 1m × 1.5 m, length, width, and height, respectively. A randomized complete block design with four replications was used for the experimental set-up had 23 treatments (Table 1). Pupae of FAW, raised in a rearing cage on maize seedlings (the second generation) were used for choice and no-choice experiments.

Twenty-five pairs of pupae with a 1:1 (male: female) ratio were released into each cage with test plants for the free-choice study and five pairs of pupae were inoculated into each cage with test plants for the no-choice study. On the ninth day, all pupae released for both experiments emerged to adults. The female adults started laying eggs after 3–4 days, and then the tested plant parts were examined by using a hand lens. The number of eggs, the egg position on the plant (bottom, middle, and upper canopy), the number of larvae, the larval weight, faces weight, and percent plant damage were recorded. The percent damage of the test crop plant was determined using a 0 to 9 scale as described by Davis and Williams (1992), where:0= No feeding symptoms or damage, 1= only pinhole damage on leaves (less than 5%), 2= Pinhole and shot hole damage to leaf (less than 10%), 3= Small elongated lesions (5 to10 mm) on 1 to3 leaves (less than 20%), 4= Midsized lesions (10 to 30 mm) on 4 to7 leaves (less than 30%), 5= Large elongated lesions (>30 mm) or small portions eaten on 3 to 5 leaves (60%), 6= Elongated lesions (>30 mm) and large portions eaten on 3 to 5 leaves,7= Elongated lesions (>30 cm) and 50% of leaf eaten, 8= Elongated lesions (30 cm) and large portions eaten on 70% of leaves, 9= Most leaves with long lesions and 100% defoliation observed, respectively.

Data analysis

Total egg counts were log-transformed before subjecting it to the analysis of variance (ANOVA) to ensure the normality of the data. The number of days required for egg hatching, larval and pupal development, adult emergence, and adult longevity were analyzed using one-way ANOVA via a general linear model (PROC GLM). The least significant difference (LSD) at the 5% level was used to separate significant. SAS software was used for data analysis (SAS Institute, 2000). Prior to analysis, data were checked for normality.

Table 1. Plant species studied in the host preference study of FAW from July to October 2021.

No.	Plant species	Family	Common name	Variety	No.	Plant species	Family	Common name	Variety
1	*Zea mays*	Grasses	Maize	Jibat	13	*Daucus carota*	Umbellifers	Carrot	DARC/9
2	*Sorghum bicolor*	Grasses	Sorghum	Melkam	14	*Brassica oleracea*	Mustards	Cabbage	Tana
3	*Vicia faba*	Fabaceae	Faba bean	Walki	15	*Lactuca sativa*	Asteraceae	Lettuce	Paris Island
4	*Cicer arietinum*	Legumes	Chickpea	Worku	16	*Swiss Chard*	Amaranthaceae	Swiss Chard	
5	*Glycine max*	Legumes	Soybean	Pawe-1	17	*Capsicum*	Nightshade	Pepper	Vigro
6	*Hordeum vulgare*	Grasses	Barley	HB-1307	18	*Solanum lycopersicum*	Nightshade	Tomato	Venis
7	*Triticum*	Grasses	Wheat	Liben	19	*Solanum tuberosum*	Nightshade	Potato	Belete
8	*Phaseolus vulgaris*	Fabaceae	Haricot bean	Awash Melka	20	*Beta vulgaris*	Amaranthaceae	Beat root	Farida
9	*Eragrostis tef*	Poaceae	Teff	Dagim	21	*Allium cepa*	Amaranthaceae	Onion	Bombay Red
10	*Johnson grass*	Grasses	False sorghum		22	*Allium sativum*	Amaranthaceae	Garlic	HL
11	*Pennisetum purpureum*	Grasses	Elephant grass	Elephant grass	23	*Brassica carinata*	Brassicaceae	Ethiopian mustard	Abesha Gomen
12	*Chrysopogon zizanioides*	Grasses	Vetiver Grass						

RESULTS

Biology of FAW

The number of eggs laid varied significantly (P<0.05) among the crop plants studied, but there was no significant variation (P>0.05) in the time taken for the eggs to hatch. The lowest mean number of eggs laid per female (32) was recorded on chickpeas, while the highest mean number of eggs (122) was laid on maize (Table 2). The incubation period of eggs ranged from 5 to 8 days (Table 4). The egg was pearly white when laid, but changed to black when aged. The larvae were green at hatching with black lines and stains. As the larvae grew, they remained green but only had blacklines on the underside. The larval period (1st instar through sixth instar) was 17.59, 19.89, 14.5, 15.75, and 15.89 days on maize, sorghum, chickpea, barley, and wheat, respectively (Table 4). The pupal period lasted between 8.54 and 9.09 days (Table 4) and pupal weight did not show much difference with respect to the host crops (Table 3).

The time taken from larva to adult was significantly different (P<0.05) among the tested crops. The highest number of days from larva to adult was recorded on sorghum (37.8 days) followed by maize (35.89 days), while the lowest duration of 31.53 days, 33.12 days, and 33.27 days on chickpea, barley, and wheat, respectively (Table 4). FAW adult counts varied from 9 to 14 in maize and sorghum, whereas 8, 5, and 2 adults were recorded on chickpeas, wheat, and barley, respectively. The cannibalism rate of FAW larvae was different for different crops (Table 3). The sex ratio of FAW did not vary among the examined crop plants (Table 3).

Table 2. Ovipositional preferences and survival rate of FAW larvae (3rd and 6th instar) to different host plants (Mean ±SE).

Treatment	Number of eggs	Number of larvae ±SD Egg Hatched	survival % 3rdinstar	6thinstar (n=20)	No. Pupa	Cannibalism %
Maize	122.0±4.3a	55.7±57b	63.2±9.1a	18.2 ± 0.84a	16.4 ± 0.64a	18
Sorghum	84.0±2.8b	57.8±4.3b	65.9±9.4a	16.4 ± 1.64b	14.4 ± 0.86b	28
Chickpea	32.0±1.6e	28.8±9.3c	46.4±14.4b	2.4 ± 0.56d	2.0 ± 0.62d	90
Barley	42.5±2.5d	86.1±6.3a	68.0±8.2a	8.2 ± 1.23bc	6.2 ± 1.82bc	69
Wheat	51.0±5.2c	83.8±6.4a	65.8±2.7a	10.4 ± 1.32b	10 ± 1.02b	50

Mean in columns separated by the same letters are not statistically different by LSD at P≤ 0.05.

Table 3. Some biological parameters (Mean ± SE) of FAW on different crops

Treatment	Pupal weight	Number of emerged adults	Sex ratio
Maize	1.12 ± 0.0038 a	14 ± 2.12a	0.52 ± 0.10
Sorghum	0.86 ± 0.0035 b	9 ± 3.21a	0.44 ± 0.28
Chickpea	0.64 ± 0.0027 c	2 ± 0.4b	0.48 ± 0.26
Barley	0.82 ± 0.0017b	5 ± 0.52b	0.52 ± 0.14
Wheat	0.84 ± 0.0019b	8 ± 3.40b	0.54 ± 0.16
LSD			NS

Mean in columns separated by the same letters are not statistically different by LSD at P≤ 0.05.

Table 4. Duration of the developmental stage of FAW on different host plants (Mean ± SE).

Treatment	Duration (days) Oviposition to hatch	1st to 6th instar	Pre-pupae	Pupae	Egg to adult
Maize	6–8	17.59±1.3ab	1.89±0.06 a	9.58±0.16ab	35.89±0.46b
Sorghum	5–8	19.89±2.2a	1.97±0.09 a	9.44±0.19ab	37. 8±0.50a
Chickpea	5–8	14.5±2.1c	1.89 ±0.08 a	8.54±0.09c	31.53±0.15d
Barley	5–8	15.78±1.2bc	1.86±0.07 a	8.86±0.24bc	33.12±0.27c
Wheat	5–8	15.89±2.2bc	1.69±0.07 b	9.09±0.11abc	33.27±0.17c

Mean in columns separated by the same letters are not statistically different by LSD at P≤ 0.05.

Feed suitability of FAW

The results of final larval weight, feed consumption, face weight, digested feed weight, and feeding time of FAW are shown in Table 5. The final larval weight that was measured on various host crops varied significantly at the P< 0.05 probability level (Table 5). The larvae feed on maize had the largest ultimate weight (128.84 mg), followed by wheat (118.42 mg), and barley (116.24 mg). The larvae fed on sorghum had the lightest recorded total weight of 112.68 mg (Table 5). The larvae fed to maize, wheat, and barley showed the maximum feed consumption, whereas the larvae fed to sorghum and chickpea had the lowest feed consumption. On the same crop plants used for testing, the largest (maize, wheat, and barley) and lowest (sorghum and chickpea) feces weight and digested feed were also noted (Table 5). The larvae that feed on wheat (6 days), barley (6.25 days), and chickpea (8 days) took a comparatively shorter time to finish the feed, while the larvae that feed on maize, sorghum took 10 days and 12.25 days to finish the feed (Table 5).

Table 5. Consumability and digestibility of different hosts for the FAW on larvae.

Treatment	Initial weight (gm) (n=10)	Final weight(mg)	Feed consumed (mg)	Feces weight(mg)	Digested feed	Feeding time(day)
Maize	1.48	128.8±12.2a	284.50±8.2a	96.83±11.21a	187.67±19.21a	10.00±0.27b
Sorghum	1.49	112.6±11.0bc	242.1±4.2c	82.70±8.76b	159.42±16.78c	12.25±0.12a
Chickpea	1.49	108.62± 9.9c	196.2± 28.4d	67.41±11.06c	128.81±13.46d	8.00±0.36bc
Barley	1.47	116.24±11.9b	268.2±36.2bc	91.41±12.30a	176.82±17.32b	6.25±0.46c
Wheat	1.47	118.42±11.9b	271.06±37.5b	92.35±12.14a	178.71±18.00b	6.00±0.42c

Mean in columns separated by the same letters are not statistically different by LSD at P≤ 0.05.

FAW host range study on different plants with no-choice test

There were significant differences among the tested crops in the oviposition preference of FAW adult moths. The number of eggs laid on different crops by the FAW adult moth ranged from 33.75 to 217.5 on the host range study in the no-choice test. (Table 6). Among the crop plants tested with no choice test, maize (217.5), sorghum (210.5), swiss chard (2010) and lettuce (2010) had the maximum number of eggs recorded followed by vetiver grass (202), cabbage (201.5), potato (198), elephant grass (193.5), teff (191.5), beetroot (187), tomato (179), barley (177.25), haricot bean (163.5), carrot (152), soya bean (140.25), wheat (136.5), chickpea (114.75), false sorghum (110.5), pepper (108), and lowest number of eggs were recorded on Ethiopian mustard (94), onion (49.5), garlic (40.5), and faba bean (33.75) (Table 6).

In the no-choice experiment, larvae preferred the majority of study crop plants (Table 6). The mean number of larvae was between 3.5 and 81.5. There was a significantly higher difference among the treatments in larval numbers. The highest numbers of larvae were observed on the maize (81.5) plant followed by the sorghum (65.5), wheat (61.2), cabbage (49), swiss chard (49), tomato (48.5), teff (46), potato (40), haricot bean (40.5), lettuce (39.5), elephant grass (38.5), barley (32.5) chickpea (30), and vetiver grass (30). The minimum larval was recorded on beetroot (29.5), pepper (25.5), false sorghum (24), soya bean (21.5), carrot (19) and. Moreover, the least number of larvae was recorded on onion (15.5), Ethiopian mustard (8.5), Garlic (5), and faba bean (3.5).

The final weight of sixth-instar FAW larvae fed on maize (5.9) and teff (4.52) was higher than that of sorghum (3.9), wheat (3.9), lettuce (3.1), beetroot (3.2), cabbage (3), swiss chard (3), barley (2.6), soya bean (2.5), chickpea (2.14), elephant grass (1.6), haricot bean (1.3), and false sorghum (1.2). The mean larvae survival percentage was 0 to 72 percent and the preference of the larvae for the vetiver grass, faba bean, carrot, pepper, tomato, potato, onion, Ethiopian mustard, and pepper was very low, and no larvae were able to survive on those plants.

According to the results of a no-choice experiment, the insect caused a significant percentage of damage to wheat (100%), chickpeas (93.8%), barley (90%), and teff (80%). Following that, different percent damage levels were recorded for maize (75%), sorghum (61.3%), cabbage (47.5%), haricot bean (45%), soybeans (40%), and false sorghum (42.5%). Damage ranged from 2.5 to 17.5% on the remaining test crop plants (swiss chard, lettuce, potato, elephant grass, carrot, tomato, carrots, onion, garlic, and faba beans) (Table 6). On the other hand, there was no percent damage recorded on pepper and vetiver grass (Figure 2). FAW caused severe damage to wheat, chickpea, barley, and teff crops and rapidly changed to the next developmental stage of the insect. However, maize, sorghum, cabbage, haricot bean, soybeans, and false sorghum were severely damaged by the larvae (Table 6).

Table 6. Oviposition, number of larvae, larval weight, and percent host crop damaged by FAW in no-choice

Treatments	Mean ±SD				
	MNEA8Ds	MLH14Ds	TLPA25ds	M%D25Ds	MLW25d (gm)
Maize	103.8±10.1a	72.4±6.2a	18.4±2.6a	59.7±8a	1.9±0.1a
Sorghum	96.0±12a	47.3±5.2bc	16.1±0.8ab	38.9±9.9b	1.8±0.1a
Faba bean	45.4±22.1fg	0.03±0.0i	0.03±0.0g	0.03±0h	0.03±0.0i
Chickpea	54.8±6.1defg	14.7±2.4fghi	16.1±1.2ab	29.6±4.7cd	1.1±0.7bcd
Soybean	61±4.4cdef	7.0±1.2hi	6.2±0.9ef	8.3±0.8g	0.5±0.2fgh
Barley	74±10.5bcd	59.1±4.2ab	11.6±cd1.6	28.2±3.3cd	0.9±0.5def
Wheat	75±3.6bcd	35.3±4.3cde	16.4±2.9ab	33.1±5.1bc	1.6±0.5ab
False sorghum	48.5±8.2efg	26.4±6.8efg	11.5±1.9cd	33.9±3.9bc	0.8±0.1ef
Haricot bean	50.2±5.2efg	8.3±2.4hi	0.03±0.0g	0.03±0.0h	0.03±0.0i
Teff	54.4±3.6defg	26.1±8.2efg	13.4±2.4bc	34.6±6.0bc	0.9±0.4def
Elephant grass	99.4±6.8a	43.1±6.2bcd	14.5±2.1bc	29.9±3.8cd	1.1±0.7cde
Vetiver Grass	78.8±4.6abc	35.6±5.1cde	0.03±0.0g	0.03±0.0h	0.03±0.0i
Carrot	0.03±0.0i	0.03±0.0i	0.03±0.0g	0.03±0.0h	0.5±0.4fgh
Cabbage	68.4±8.0bcde	8.6±1.8hi	9.4±1.7de	29.9c±3.8d	0.7±0.5efg
Lettuce	73.8±18.2bcd	26.9±3.5efg	12±2.8cd	39.1±8.3b	1.0±0.2cde
Swiss Chard	68.2±6.4bcde	30.4±8.2def	13.8±2.4bc	39.1±8.3b	1.4±0.6abc
Pepper	0.03±0.0i	0.03±0.0i	0.03±0.0g	0.03±0.0h	0.03±0.0i
Tomato	39.8±11.2gh	18.9±6.1fgh	6.3±1.5ef	20.5±4.1ef	0.2±0.0hi
Potato	20.6±2.2hi	12.5±4.1ghi	5.8±1.2f	21.1±6.7def	0.2±0.0hi
Beetroot	0.03±0.0i	0.03±0.0i	0.03±0.0g	0.03±0.0h	0.03±0.0i
Onion	0.03±0.0i	0.03±0.0i	0.03±0.0g	0.03±0.0h	0.03±0.0i
Garlic	0.03±0.0i	0.03±0.0i	0.03±0.0g	0.03±0.0h	0.03±0.0i
Ethiopian mustard	0.03±0.0i	0.03±0.0i	0.03±0.0g	0.03±0.0h	0.03±0.0i
CV	31.77	54.62	28.72	30.60	51.12
LSD	9.87	16.26	3.31	8.88	0.47

Experiment in greenhouse

MNEA8Ds, mean number of eggs after 8 days; MLH14Ds, mean larvae hatch 14 days; M%D25Ds, Mean % damage after 25 days; TLPA25ds, total larval/plant after 25 days (using destruction method); LS, Larvae Survival percentage; LW25d, Larval weight on 25 days, and FW25ds, Frass weight on 25th day.

Table 7. Oviposition, number of larvae, larval weight, and percent host crop damaged by FAW in a choice experiment in a wirehouse.

Treatment	MNEA8Ds	MLH14Ds	TLPA25ds	LS%	M%D25Ds	LW25d	FW25ds
Maize	217.6±25.9a	81.5±2.3a	58.8±7.2a	72.15	75±5.8c	5.9±0.7a	17.66a
Sorghum	210.5±43.9a	65.5±7.7b	46.1±5.0ab	70.6	61±6.3d	3.9±0.1bc	13.09cd
Faba bean	33.8±19.5i	3.5±0.1j	0.03±.01g	0.86	2.5±2.9hi	0.03±.01j	0.03nm
Chick pea	114.8±13.3fg	30±2.2efg	18.64±4.5b	62.13	93.8±7.5a	2.1±0.2efg	15.11b
Soya bean	140.3±17.3defg	21.5±4.9hfg	8.4±1.6d	39.07	40±14.1e	2.5±0.3def	8.22gh
Barley	177.3±27.2cde	32.5±8.3ef	16.6±1.4b	51.08	90±8.2a	2.6±0.3de	13.82bcd
Wheat	136.5±61.7efg	61.25±5.4cb	42.2±2.9ab	69.48	100±0.0a	3.9±0.1bc	14.46bc
False sorghum	110.5±47.5fg	24±3.7hfg	16.5±4.8b	68.75	42.5±12.6e	1.2±0.1hi	9.79fg
Haricot bean	163.5±46.2cde	40.5±2.7ed	10.8±2.6c	26.67	45±12.9e	1.3±0.1gh	8.62gh
Teff	191.5±55.3abc	46±2.3d	19.4±5.2b	42.17	80±16.3bc	4.5±0.4b	13.96bcd
Elephant grass	193.5±21.0abc	38.5±7.4ed	19.8±5.3b	51.43	11.3±4.3fgh	1.6±0.3fgh	7.11hi
Vetiver Grass	202.0±12.1ab	30±5.2efg	0.03±.01g	0.10	0.0±0.0i	0.01±0.0j	2.58lm
Carrot	152±22.6cdef	19±5.0hig	0.8±0.02f	4.21	2.5±0.9hi	0.12±0.0j	5.99ij
Cabbage	201.5±22.9ab	49±8.8cd	18±7.5b	36.73	47.5±12.6e	3.0±0.2cd	12.31de
Lettuce	212.0±12.1a	39.5±5.5ed	14±5.7c	35.44	13.8±5.5fg	3.1±0.2cd	12.25de
Swiss Chard	210.0±23.4a	49±8.9cd	16.8±69b	34.29	17.5±7.6f	3.0±0.4cd	13.93bcd
Pepper	108 ±10.6fg	25.5±1.1 hfg	0.03±.01g	0.12	0.0±0.0i	0.03±.01j	0.03nm
Tomato	179±36.9cde	48.5±2.5d	2.2±1.1e	4.54	3.8±1.5ghi	0.3±0.11ij	4.90jk
Potato	198±12.5abc	40±6.7ed	2.0±0.4e	5.00	3.8±1.5ghi	0.8±0.1hij	5.34ijk
Beetroot	187±18.9cd	29.5±4.2efg	0.8±0.2f	2.71	17.5±5.0f	3.2±0.3cd	10.80ef
Onion	49.5±11.1hi	15.5±4.8hij	0.7±0.2f	4.52	6.3±2.5ghi	0.8±0.1j	2.03lmn
Garlic	40.5±26.6i	5±1.6j	0.7±0.2f	14.0	2.5±1.9hi	0.05±.02j	2.26lmn
Ethiopian mustard	94.0±13.4gh	8.5±2.1ij	0.5±02f	5.88	1.3±0.2hi	0.012±.01j	0.65n
CV	22.0	25.7	22.32		23.39	36.69	13.08
LSD	7.7	12.2	2.52		10.88	0.95	1.87

MNEA8Ds, mean number of eggs after 8 days; MLH14Ds, mean larvae hatch 14 days, M%D25Ds; Mean % damage after 25 days; TLPA25ds, total larval/plant after 25 days (using destruction method), and MLW25d, Mean larval weight on 25 days.

FAW host range study on different plants with choice test

There was a significant difference in the oviposition preference of FAW in some of the crop plants studied in the choice test experiment (Table 7). The highest number of eggs was recorded on maize, elephant grass, sorghum, vetiver grass, barley, cabbage, swiss chard, wheat, lettuce, soya bean, chickpea, teff, haricot bean, false sorghum, faba bean, tomato, potato with 103.8, 99.4, 96, 78.8, 74, 68.4, 68.2, 65, 63.8, 61, 54.8, 54.4, 50.2, 48.8, 45.4, 39.8, and 20.6, respectively. In the choice tests, no egg masses were laid on carrot, pepper, beetroot, onion, Ethiopian mustard, and garlic (Table 6).

The number of FAW larvae that emerged from each of the crop plants under study varied significantly from crop to crop. There were about 72.4 observed larvae in maize; while 59.1, 47.3, and 43.1 larvae were recorded in sorghum, elephant grass, and barley, respectively. However, there were about 35.6, 35.3, 30.4, 26.9, 26.4, and 26.1 larvae in the vetiver grass, wheat, Swiss chard, lettuce, false sorghum, and teff, respectively. There were 7.06 to 18.9 observed larvae on tomato, chickpea, potato, haricot bean, and soya bean. There was no larval emergence seen on the remaining crop plants (faba bean, carrot, pepper, beetroot, onion, garlic, and Ethiopian mustard).

On the tested plants lowest to highest larval weight showed when compared to each other. The larval weights of those that consumed swiss chard, sorghum, wheat, and maize ranged from 1.95 to 1.4 gm, whereas those that consumed other crops ranged from 1.0 to 0.5 gm (Table 7). The choice experiment also revealed the FAW damage levels, with the maximum and lowest values being 59.72 and 8.33 percent, respectively. The mean percent damage of FAW larvae on choice experiment after 25 days on different host crop plants was significantly different at $P < 0.05$. The highest percent damage by the FAW insect pest was observed in maize (59.72), sorghum (38.9), lettuce (39.1), swiss chard (39.1), wheat (33.1), false sorghum (33.9), teff (34.6), chickpea (29.6), elephant grass (29.9), cabbage (29.9), barley (28.2), and the lowest in potato (21.1) tomato (20.5) and soybean (8.33). FAW did not cause any damage to faba bean, haricot bean, vetiver grass, carrot, pepper, beetroot, onion, garlic, and Ethiopia mustard (Figure 1).

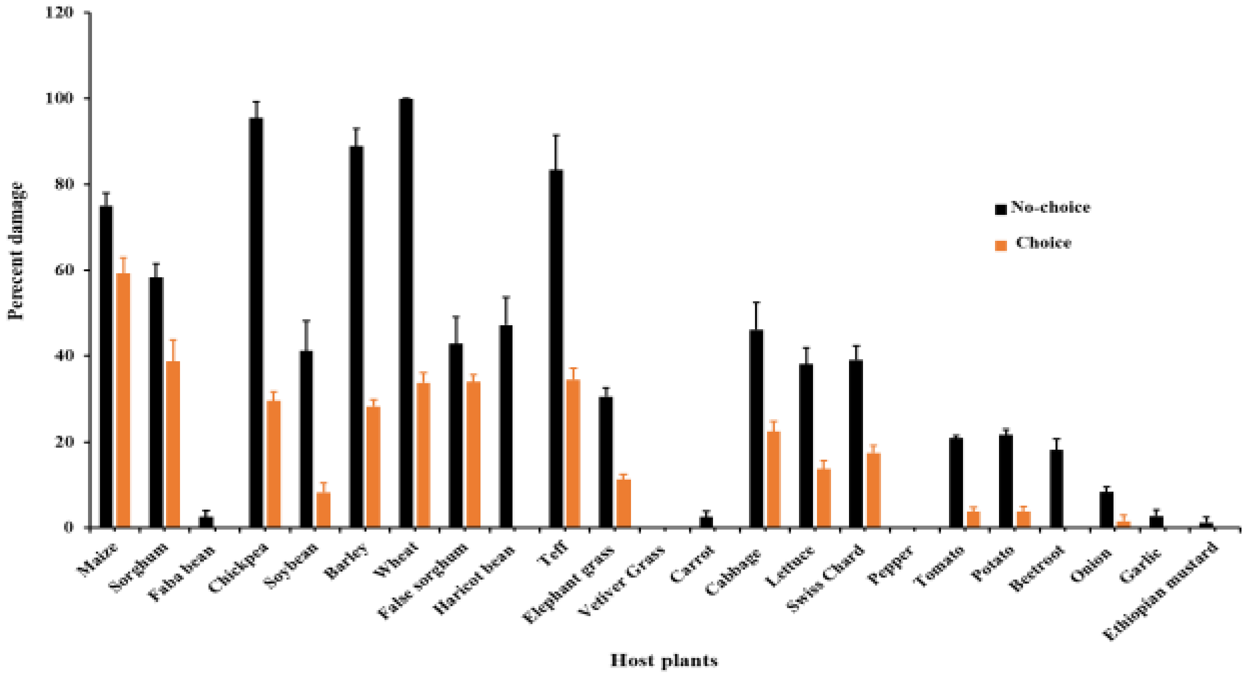

Figure 1. Percentage damage caused by FAW in both the no-choice (black) and choice experiments (dark red) in different host plants.

DISCUSSION

The biology of FAW was investigated in maize, sorghum, wheat, barley, and chickpea. The crop plants in the current study were selected based on their cultivation status in different parts of the country and the prevalence of FAW on the crops. A high number of eggs were laid on maize and sorghum which are expected to be the main host of the FAW. Similarly, FAW larvae highly survived on cereal crops (maize, sorghum, barley, and wheat), whereas, a low number of survivals were observed on chickpea. This phenomenon is directly related to the palatability and physiological or biochemically content of the crops (Barros *et al.*, 2010; Wijerathna *et al.*, 2021). Therefore, the naturally occurring biochemicals such as 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA) and 6-methoxy-benzoxazolin-2-one (MBOA) in maize, sorghum, and wheat are more similar to the compounds produced by pulse and cash (cotton) crops (Hardke *et al.*, 2015).

The percentage of cannibalism was much higher among FAW larvae confined on chickpea plants than it was among those fed on cereals (maize, sorghum, wheat, and barley). These may be due to proliferation and vegetative biomass, on maize and sorghum the larvae tend to disperse throughout the plant and they get the chance to hide in or under leaf, leaf sheath, and shoot, these reduce cannibalism among larvae. Chickpea have small biomass and larvae remain in very close proximity to each other, thus leading to an increase in cannibalism percentage (Raffa 1987). The other reason may induce defenses in plants to reduce herbivory by increasing cannibalism (Orrock *et al.*, 2017).

The host preference study was also conducted using both choice and nonchoice tests. Thus, major crops grown in Ethiopia were assessed for host preference of FAW under greenhouse and wire-house. Accordingly, the Gramineae family including maize, sorghum, elephant grass, and vetiver grass, and vegetables like cabbage, lettuce potato, and swiss chard were highly preferred for oviposition both at choice and non-choice test. oviposition preference of lepidopterans in general, FAW in particular, influenced by leaves surface and appearance, chemical and tactile cues in host plants. With this regard, strong tactile stimuli for grooved and pitted surfaces for ovipositional behavior and preference were observed in FAW (Rojas *et al*., 2003), and *Spodoptera exigua* (Greenberg *et al*., 2002). Moreover, the naturally occurring chemical compounds, terpenes, found in maize, sorghum, and wheat were reported as the most attractive odor for oviposition of FAW (Nandhini *et al*., 2022; Birhanu *et al*., 2023). Our current study justifies these findings as more eggs were oviposited on maize, sorghum, and wheat which are characterized by grooved and pitted leaves surfaces. Similarly, the larval survival rate on these crops was high which indicates the larval preference for the crops. This could be because of various reasons such as the proliferation of biomass and nutritional content. The feeding and ovipositional responses of FAW on different hostplants revealed that maize and sorghum are the most preferred crops (Nandhini *et al*., 2022; Birhanu *et al*., 2023; Tiwari, 2022; Wijerathna *et al*., 2021)

Oviposition preference does not necessitate the offspring's performance in the FAW (Sotelo-Cardona *et al*., 2021). In our current study; however, the oviposition preference towards vegetables was high during no-choice, it was comparatively low during choice. This is because, during the choice test, other more preferred hosts like maize and sorghum were available for preference. This indicates that the adult prefers host crops for oviposition. Consistent with the oviposition and feeding preference result, the grass family and vegetables (cabbage, lettuce, and swiss chard) were highly damaged by the larvae.

In general, the choice and non-choice tests indicate that even though the ovipositional and feeding preference of FAW varies among the host plants, the insect can survive and complete its life cycle on both the grass family and some of the vegetables.

CONCLUSIONS AND RECOMMENDATIONS

The findings of this study are important for understanding the biology, feeding, and oviposition preferences of FAW in order to create and design sustainable management options. The results of the present study are necessary to know the biology, feeding, and oviposition preferences of FAW which will help create and design sustainable management options. The most preferred host plants for FAW insect pest oviposition, survival rate, and percent damage of larvae on different crop plants were identified under no-choice and choice experiments; whereas some of the tested crop plants were not preferred by the FAW. Therefore, the utilization of those crop plants in cropping systems for crop rotation and intercropping reduces the impact of FAW. Also, the study provides elaborate information concerning the biology, survival, and morphometric parameters of various stages of FAW on different crops which are important in developing management strategies.

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Annex. 1 Figures 1 and 2 show photos of the host rage experiment on choice and no-choice.

Annex Figure 1. *Spodoptera frugiperda* larvae damage in the different crop plants tested in the no-choice experiment. A: Ethiopian mustard, B: Onion, C: Swiss chard, D: Cabbage, E: Soyabean, F: Haricot bean, G: Chickpea, H: Faba bean, I: Fales sorghum, J: lettuce, K: Garlic, L: Tomato, M: Potato, N: Pepper, O: Vetiver Grass, P: Wheat, Q: Barley, R: Sorghum, S: maize, T: Elephant grass

Annex Figure 2. *Spodoptera frugiperda* larvae damage in the different crop plants tested in the choice experiment.