Comparative Evaluation of the Performance of Castor Leaf and Three Artificial Diets in the Rearing of Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

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Abstract

Fall armyworm (FAW) is the most recent destructive pest of maize crop in Africa. The rearing of FAW in large number using artificial diets is required for intensive study on its biology, damage potential and possible control strategies. This study evaluated the reproductive performance of FAW on castor plant leaf and diets prepared with cowpea flour, soya bean flour and corn flour. Each food source was replicated four times and arranged in a Completely Randomized Design. Biological parameters such as larval and pupal developmental periods, pupal weight, longevities of mated and unmated adult female; and larval and pupal survival rates were recorded on each diet. Data was analyzed using ANOVA and significant means were separated using LSD (P<0.05). Shorter larval developmental periods were recorded on cowpea diet (14.50 days), soya bean diet (18.75days) and castor leaf (15.25 days) and the longest larval developmental period on corn diet (29.50 days). Similarly, cowpea diet, soya bean diet and castor leaf significantly enhanced the pupation, adult emergence, fecundity of female and longevity of FAW than corn diet. However, cowpea flour formulated diet performed well above other diets on all biological parameters measured. Cowpea diet is highly recommended for the mass rearing of FAW in the laboratory.

Keywords: Diets, Fall armyworm, longevity, fecundity, emergence

Introduction

Fall armyworm (FAW), *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae) is an invasive and polyphagous insect pest which preferentially feeds on grain crops (Bengyella *et al.,* 2021). It is native to North and South America and was first reported in Nigeria and São Tomé in 2016 (Goergen, 2016). It spreads to other African countries such as Kenya, Uganda, Rwanda, Ethiopia and Tanzania; and thereafter throughout Sub-Saharan Africa (SSA) (Timilsena 2022). The fast spread of FAW across the globe may not be unconnected to poor sanitary laws and migratory behaviour of the pest (Faulkner, 2017; Early, 2018). Since the occurrence, spread and establishment of the FAW in Africa, losses as a result of FAW infestations in maize, sorghum, rice and sugarcane in African countries have been estimated at USD13.38 billion (Abrahams *et al.,* 2017). Research findings showed that in most of SSA; FAW has caused economic damage to its main host, maize crops in over 44 African countries which accounts for the loss of more than 25.5 billion US dollars (Bengyella *et al.,* 2021).

The development of fall armyworm consists of egg, six larval instars, pre pupa and adult stages. The developmental cycle of FAW reported in Sub-Saharan Africa takes an average of 25 days spread across different stages of development which include egg (5 days), larva (14 days), pupa 7days) (Tendeng *et al.,* 2019). However, there could be variations depending on environmental factors and host species. In Nigeria, the larval developmental period of FAW reported on maize, cassava and cowpea leaves were 14, 16 and 17 days, respectively (Odeyemi *et al.,* 2021).

The use of artificial diet in the rearing of insects, especially *S. frugiperda* under laboratory conditions has been reported in different studies (Silva and Para, 2013; Pinto *et al.,* 2019). Some of the artificial diets reported in the rearing of FAW include standard diet based of beans (*Phaseolus vulgaris* L. var. carioca), a diet with the substitution of corn flour for wheat germ, and a diet in which beans were replaced with green corn (fresh corn) (Pinto *et al.,* 2019). Others include Chickpea flour-based diet, Black gram flour based diet, Green gram flour based diet and Soybean flour based diet (Lekha, 2020). Since the outbreak of FAW in Nigeria, information on the use of artificial diets in its mass rearing has not been reported. However, the use of artificial diets in the rearing of insects provides information on the biology, behaviour, and nutritional requirements of insects, and such information is basic in the formulation of appropriate and efficient integrated pest management (IPM) programme. Therefore, this study was carried out to evaluate the efficiency of different artificial diets on the development of FAW.

Materials and Methods

Preparation of artificial diet

The artificial diets used in this study were based on the results of the preliminary work on FAW diet. The experiment was carried out at insect rearing unit (IRU), International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The diets consisted of four different food sources (3 formulated diets and 1 natural diet). The diets one (D1), two (D2) and three (D3) were formulated using cowpea, soya bean and corn flour respectively, while castor plant leaf served as the natural diet (D4). The detailed composition of each artificial diet is stated in Table 1.

Culturing of *S. frugiperda*

Fall armyworm caterpillars were collected from leaves and stem of infested maize plants from maize fields in IITA, Ibadan, Nigeria and reared in plastic cages in the laboratory. When molted to pupae, the insects were collected and placed in PVC cages measuring 21 cm height x 10 cm diameter until adult emergence, and adults were maintained on 10% sugar solution. Egg batches deposited by these adults were incubated in glass tubes measuring 2 cm diameter x 8 cm height until the eggs were hatched into first larval instars.

Fifty (50) newly hatched larvae were collected from the insect culture and introduced on each food source in plastic petri dish and allowed to grow until pupation. Only castor plant leaf food source was replenished every day. Each food source was replicated four times and arranged in a Completely Randomized Design. The rearing was carried out at 25ºC, 70% RH and photoperiod of 12 hours of light and 12 hours of darkness. Data were taken on biological parameters such as larval developmental period, pupal developmental period, pupal weight,

Table 1: Artificial diet composition for *Spodoptera frugiperda*

Constituent	D1	D2	D3	D4
Cowpea (g)	240.0g	-	-	-
Soya-Bean (g)	-	240.0	-	-
Corn-Flour (g)	-	-	240.0	-
Wheat Germ (g)	120.0	120.0	120.0	
Wild Host (Castor oil plant leaf) (g)	-	-	-	16.0
Brewer Yeast (g)	72.0	72.0	72.0	-
Ascorboc Acid (g)	7.3	7.3	7.3	-
Scorbic (g)	2.4	2.4	2.4	-
Methyl Parahydroxybenzoate (g)	4.4	4.4	4.4	-
Vitamin Solution (ml)	10.0	10.0	10.0	-
Formaldehyde (ml)	6.0	6.0	6.0	
Agar (g)	20.0	20.0	20.0	-
Distilled Water (ml)	1.0	1.0	1.0	-

percentage pupation and percentage emergence. Larval developmental period was measured as the number of days from egg hatching to pupation, pupal developmental period was measured as the number of days taken from the first day of pupation till adult emergence and pupal weight was taken using a digital weighing balance [Model: Pioneer PA413 (max 410g x 0.001g)]. Percentage pupation and percentage adult emergence were calculated using the following formulae:

$$Percentage\ pupation = \frac{Number\ of\ pupal\ formed}{Initial\ number\ of\ larvae} x100$$

$$Percentage\ adult\ emergence = \frac{Number\ of\ adult\ emerged}{Initial\ number\ of\ pupae} x100$$

Two pairs of teneral adults males and females of *S. frugiperda* after emergence were caged in four cylindrical PVC cages measuring 10 cm diameter and 20 cm height lined with a paper sheet. Adults FAW were fed with 10% sugar solution on a piece of soaked cotton wool packed inside a plastic cup. Data on female fecundity was measured as the total number of eggs laid by adult female and longevities of mated and unmated female adults were taken as the number of days from adult emergence till death. Different growth and fitness indices were calculated according to Setamou *et al.,* 1999; and Amer and El-Sayed, 2014 using the following equations.

$$Larval\ growth\ index = \frac{Pupation\ (\%)}{Larval\ period\ (days)}$$

$$Pupal\ growth\ index = \frac{Emergence\ (\%)}{Pupa\ period\ (days)}$$

$$Immature\ growth\ index = \frac{Emergence\ (\%)}{Immature\ stages\ (larval\ period + pupal\ period\ (days))}$$

$$Standardized\ growth\ index = \frac{Pupal\ weight}{Larval\ period\ (days)}$$

$$Fitness\ index = \frac{Pupation\ (\%)\ x\ Pupal\ weight}{Larval\ period + Pupal\ period}$$

Statistical analysis

Data were analysed using Analysis of Variance (ANOVA) using SAS statistical software and treatment means were separated with Least Significant Difference (LSD) ($p< 0.05$).

Results

There were significant ($F=170.22, p<0.0001$) differences in the larval developmental periods of FAW among the different food sources (Table 2). The larval developmental period of FAW reared on corn flour diet was significantly longer than on other food sources. The developmental periods of FAW larvae reared on cowpea flour diet and castor plant leaf were not significantly different but significantly shorter than what was observed on soya bean diet. The larval ($F=65.93$, $p<0.0001$) and pupal ($F=74.68$, $p<0.0001$) survivals of FAW recorded among the four food sources were significantly different. The highest larval and pupal survivals were observed on cowpea flour diet and the least on corn flour diet. Significant differences among the food sources were also observed in pupal weight ($F=13.35$, $p<0.0004$), adult fecundity ($F=5.91$; $p = 0.0102$), mated female longevity ($F=4.71$; $p=0.0214$) and unmated female longevity ($F=5.13$; $p=0.0163$), but the effect of different food sources was not significant in the pupal period ($F=2.27$; $p=0.1323$). The lowest pupal weight recorded on corn flour diet was significantly different from the pupal weights on other food sources. The differences in pupal weights on soya bean and cowpea flour diets were not significant, but significantly higher than the weight on castor leaf. The number of eggs laid by adult females reared on cowpea flour and soya bean diets were not significantly different, however, it was significantly higher than the number of eggs laid by female adults reared on corn flour diet. The longevities of mated and unmated FAW females reared on cowpea and soya bean flour diets were not different but significantly longer than those reared on castor leaf and corn flour diet. The highest growth indices were recorded on cowpea flour diet followed directly by castor leaf, while the lowest growth indices were recorded on corn flour diet (Table 3).

Discussion

The results of this study showed that larval developmental period of *S. frugiperda* varied among the different food sources. The differences in the nutritional quality of each diet could be the reason for the observed differences in the duration of larval period. The duration of *S. frugiperda* larval period on protein-based food sources, cowpea (14.5 days) and soyabean (18.75 days) recorded in this study is similar to 14. 0–18.50 days earlier recorded on protein-based diets (Lekha *et al.,* 2020). The biological performance of insect is not unconnected with the quality and quantity of food taken during the larval stages (Pinto *et al.,* 2019). The shorter larval developmental periods of *S. frugiperda* on cowpea diet, castor leaf and soya bean diets suggested that these diets are suitable than corn flour diet in the rearing of *S. frugiperda*. The longest larval developmental period recorded on corn flour diet might be due to low nutrient content, especially protein, associated with the diet. Earlier studies have reported that corn has lower protein content than beans (Farinelli and Lemos, 2010; Alves *et al.,* 2015). In addition, the lower performance of *S. frugiperda* on corn flour diet in terms of larval growth and development might be as a result of the high carbohydrate content than that of soya bean and cowpea. Carbohydrate has greater surface stiffness when compared to the protein-based diets; consequently, this factor may have reduced the diet's ingestion and consumption by *S. frugiperda* larvae.

The higher developmental rate, pupation and adult emergence on both cowpea and soya bean diets compared to lower developmental rate, pupation and adult emergence on corn flour diet showed that corn flour diet is not suitable for the mass rearing of *S. frugiperda*. In general, the insects fed on high-quality hosts have shorter duration of the whole biological cycle and higher growth rate (Awmack and Leather, 2002; Cunha *et al.,* 2008; Vellau *et al.,* 2013).

The weights of *S. frugiperda* pupae reared on cowpea and soya bean diets were bigger than those reared on corn flour diet. The high fecundity recorded on adults reared on cowpea and soya bean diets might be connected to the size of pupae raised on the two diets. Studies have reported the significant correlations between pupal weight and total number of eggs laid per female in insects (Parry *et al.,* 2001; Calvo and Molina 2005). The number of eggs laid by insects is directly related to the availability of nutrients in the female's body,

Table 2: Mean values of different biological parameters of fall armyworm reared on different food sources

Diets	Biological parameters							
	Larval period (days)	Pupation (%)	Pupal Weight (g)	Adult emergence (%)	Adult Fecundity	Pupal period (day)	Longevity of mated female (day)	Longevity of unmated female (day)
Cowpea flour based diet	14.50±0.29	97.00±1.00	2.38±0.06	89.50±3.40	1175.00±85.39	8.75±0.48	15.50±0.29	11.25±0.75
Castor leaf	15.25±0.25	82.00±2.00	2.18±0.03	76.00±2.31	885.00±65.64	8.75±0.48	12.50±0.87	8.25±1.11
Corn flour based Diet	29.50±0.65	39.00±4.20	1.96±0.03	26.00±4.76	862.50±23.94	8.75±0.25	10.75±0.85	8.00±0.40
Soya-beans based diet	18.75±0.75	66.00±3.83	2.39±0.08	56.00±1.00	1050.00±50.00	10.00±0.41	13.25±1.31	10.75±0.48
LSD (0.05)	1.63	9.82	0.17	9.82	186.62	1.28	2.80	2.28

Table 3: Growth indices and fitness index of Spodoptera frugiperda on different diets

Diet	Growth index				
	Larval	Pupal	Immature	Standardized	Fitness
Cowpea flour based	6.62	9.71	3.66	0.16	9.83
Castor leaf	5.25	8.23	3.00	0.14	7.27
Corn flour based	1.18	2.29	0.52	0.07	1.79
Soyabean flour based	3.2	5.6	1.95	0.13	4.99

which in turn is determined by the quality of food taken and assimilated during the larval stage (Tendeng *et al.,* 2019).

The ranges of life spans of mated and unmated females of *S. frugiperda* was longer on protein diets than on corn flour and castor leaf diets. This is comparable to the range reported by Truzi *et al.* 2021 but shorter than the report of Bernardi et al. (2014), Pinto et al. (2019) and Navasero *et al.* 2021. All the growth indices showed that *S. frugiperda* performed better on cowpea diet and castor leaf with the least performance on corn flour diet. For the most species of insects, developmental stage of larval, pupa weight and number of eggs laid by female can be used as criteria to determine the best host plants for insects (Greenberg *et al.,* 2002; Xu *et al.,* 2010).

Conclusion

In conclusion this study shows that cowpea based artificial diet has a potential to provide the adequate basic nutrients for the development, growth and reproduction of S. frugiperda and could therefore be useful for the mass rearing of this insect in the laboratory.

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Competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

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