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Biology of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on Rice and Different Corn Varieties

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Rice and corn are one of the most important crops in the Philippines. Several insect pests contribute to the losses and low yield of these crops. The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), was recently reported to cause economic damage to corn. Also, this insect consists of two genetically differentiated strains namely, the corn strain and the rice strain. This study was conducted in a laboratory conditions to evaluate the biological parameters of FAW on rice and corn varieties. Newly hatched larvae were fed such as the open pollinated variety (OPV), traditional variety, Macho F1 (hybrid), NK 6410 (genetically modified organism), and rice variety, RC 226. Duration of larva, prepupal, pupal, and larva-adult period, pre-oviposition, oviposition, and post-oviposition period, number of egg mass, fecundity, sex ratio, and survivability of larva to adult of different crops were evaluated. The results showed that the duration of development from egg to adult in Macho F1 and NK 6410 with an average duration of 24.58 and 24.66 d was significantly shorter than OPV, traditional variety, and rice variety, RC 226. The number of eggs laid by females reared on Macho F1, NK 6410, and OPV, with a mean of 1125.60, 1176.80, and 1049.40, respectively, were significantly greater than the traditional variety, tinigib, and rice RC 226. Different corn varieties and rice did not affect the male and female ratio, longevity, and survivability. The results of this study will provide insights into formulating management strategies for fall armyworm.

Keywords: fall armyworm, *Spodoptera frugiperda*, larva, corn, rice, tinigib

INTRODUCTION

Insects are considered one of the successful organisms because of their fast dispersal and high ability to adapt from the changing environment. The earliest record of fall armyworm in the Philippines was reported by Navasero et al. (2019). It was recorded in 17 municipalities and ten provinces in the Philippines from June to December 2019, where climatic conditions favor their development, survival, reproduction, and distribution (Early et al. 2018). The breeding of fall armyworm can reach six and two generations per year in the warm and cold regions respectively (Hardke et al. 2015). It has a fast dispersal and migratory behavior in the tropics (Hardke et al. 2015). Due to this ability, Hardke et al. (2015) classified *S. frugiperda* as a sporadic pest.

As a sporadic and highly polyphagous pest, *S. frugiperda* eats almost every plant section of its host. Young larvae feed on the surface of young corn leaves, leaving white papery patches known as windowpanes. Seedlings, foliage, tassels, husks, cobs, and developing kernels are among the tissues consumed by older larvae, which have stronger mandibles and can cut vast parts of the plant tissues that contain high silica content (Goergen et al. 2016).

The invasion of fall armyworm in the country leads farmers to use insecticide as an urgent response to minimize its damage and slow its dispersal. Insecticides play a vital role in the management of fall armyworm, but there are reports of the development of fall armyworm populations resistance to insecticide (Zhang et al. 2020). Therefore, being knowledgeable on the biological characteristics of *S. frugiperda* on different host plants could help develop effective and efficient strategies to suppress and manage this economically important pest (Tisdale and Sappington 2001). There are other host plants known that differentially affect the life parameters of *S. frugiperda* (Tsai and Wang 2001). These plants may exhibit different resistance mechanisms against the insect pests. Among the three resistance mechanisms in plants, antibiosis is potential against sporadic and mobile pest like *S. frugiperda* (Kennedy et al. 1987).

The level of reproductive ability and overall survival of insects is directly influenced by the quantity and quality of the food they consume. Therefore, the nutritional quality of the host plants determines the health of the insects that feed on them. As a result, the adoption of resistant cultivars can be incorporated into an integrated pest management strategy for FAW, in addition to chemical and biological control (Omoloye and Vidal 2007). Establishing an IPM approach requires a solid understanding of the biological characteristics of the life history of pests. The population growth rate of the pest that is currently present, as well as the generations that will follow, can be determined using these biological factors (Frei et al. 2009).

The host plants of *S. frugiperda* were summarized by Montezano et al. (2018), and a total of 353 plant species belonging to 76 families were recorded. However, despite that *S. frugiperda* is an economically important pest of corn, there is no published article regarding its different life-history traits. Therefore, this research gives new insight into the aspect of biological parameters of the life history traits of *S. frugiperda* on different corn varieties and rice. This study aimed to assess the life cycle of *S. frugiperda* to different corn varieties and rice, and conduct a comparative analysis of the biological parameters of this pest reared on different corn varieties under laboratory conditions.

MATERIALS AND METHODS

Stock Colony Preparation of *S. frugiperda*

Field collection, maintenance of stock colony, and life history observation followed the procedure of Agravante et al. (2022). Collected larvae were reared in an aerated plastic container and provided with leaves of an open-pollinated corn cultivar as food. Corn leaves were replaced everyday. Third instar larvae were reared separately in a small, aerated plastic container. Larvae were kept in the rearing room until pupation occurs. The sex of pupae was determined and classified then placed in a separate aerated container. Observation of pupae was done daily until moths' emergence. Following Schlemmer's (2018) rearing procedure, a pair of male-female fall armyworm pupae were kept in the rearing room with a modified oviposition chamber. After the moth's emergence, cotton that was soaked in a 10% sugar solution as food was provided. A glass cage covered with a mesh net was used as an oviposition chamber to allow aeration and avoid moths from escaping. A potted corn plant is placed inside for oviposition. The corn was observed daily for the batches of egg and replaced every day. This served as a parental stock of *S. frugiperda* colony in the laboratory. All setups in the laboratory were at 25 - 28°C, ranging to 75 - 85 relative humidity, and photoperiod of 12D.

Host Plant

The host plants used in the study were open pollinated variety of corn, traditional variety of corn (Tinigib), Corn var. Macho F1, Corn var. NK 6410, and rice var. RC 226. Corn varieties used in the experiment were the most commonly planted varieties based on the results of the survey. Corn were planted in the field every 3 d and free from insecticide application, while rice were planted in pot every 3 d following farmers agronomic practices.

Life History

Newly hatched larvae of *S. frugiperda* from the stock colony were transferred in a microwavable BPA-free containers (17 cm L x 11.5 cm W x 6.6 cm H). Each container contained fresh leaves examined host plant and ten larvae in each treatment. Treatments were replicated five times in a completely randomized design.

At the start of the experiment, leaves were replaced daily for continuous larval feeding. The observation of the head capsule determined molting. Sixth larval instars were transferred in a separate container for pre-pupation and pupation. Duration of the larval, prepupal, pupal, larva-adult period, egg to adult survivability, and male to female ratio were determined.

After adult emergence, a pair of male and female moth was introduced into an egg-laying container with a hole covered with a mesh net for continuous airflow to determine the pre-oviposition, oviposition, post-oviposition period, and adult male and female longevity. The egg-laying container was supplied with a 10 - 15% honey solution for feeding moths. Egg masses and the number of eggs from each adult pair were also counted.

Data Analysis

All the data on biological parameters of *S. frudiperda* were subjected to a one-way analysis of variance (ANOVA) using the statistical software STAR. Statistical differences among means were evaluated using the least significant difference (LSD) test at α = 0.05.

RESULTS

The biological characteristics of FAW differed depending on the food source (plant species) (Table 1). The larval stage duration for GM Corn-NK 6410 and Hybrid (Macho

Table 1. Life cycle (mean ± SD) of *Spodoptera frugiperda* fed with different corn varieties and rice.

Host Plant	Duration (days)						
	Larva (N=50)	Pre-pupa	Pupa	Egg-Adult	Pre-oviposition	Oviposition	Post-oviposition
OPV Corn	14.49 ± 0.39[a]	1.22 ± 0.08[a]	8.65 ± 0.35[a]	26.36 ± 0.47a	3.53 ± 0.19[a]	3.33 ± 0.24[bc]	3.53 ± 0.56
RICE (RC 226)	14.41 ± 0.19 [a]	1.23 ± 0.11[a]	8.81 ± 0.57[a]	26.45 ± 0.62a	3.53 ± 0.19[a]	2.80 ± 0.69[c]	3.47 ± 0.19
Traditional Corn (Tinigib)	14.07 ± 0.44 [ab]	1.15 ± 0.06[ab]	8.09 ± 0.26[b]	25.31 ± 0.57b	2.47 ± 0.38[b]	3.80 ± 0.38[ab]	3.87 ± 0.44
Corn- NK 6410 Corn (GM)	13.60 ± 0.44 [bc]	1.08 ± 0.04[bc]	7.98 ± 0.29[b]	24.66 ± 0.33bc	2.33 ± 0.24[b]	4.00 ± 0.33[a]	4.07 ± 0.43
Sweet Corn (Macho F1)	13.52 ± 0.36 [c]	1.04 ± 0.05[c]	8.02 ± 0.33[b]	24.58 ± 0.44c	2.47 ± 0.38[b]	3.78 ± 0.25[ab]	3.74 ± 0.15

*Mean (± SD) followed by the same letter in the column for each species did not differ statistically (Tukeys's HSD Test, $p \leq 0.05$).

F1) was shorter than for Open-pollinated variety (OPV), native corn (tinigib), and rice (RC 226). NK 6410, Macho F1, and tinigib have the fastest pupal development times. During the pre-oviposition stage, OPV and rice lasted longer than NK 6410, Macho F1, and tinigib. NK 6410, Macho F1, and tinigib, on the other hand, have a longer oviposition period than open-pollinated varieties of rice. Overall, the time from egg to adult for NK 6410 and Macho F1 was shorter than for tinigib, open-pollinated variety, and rice.

There was no significant change in the sex ratio, adult longevity, or survivorship of FAW fed different corn varieties and rice (Table 2). FAW reared on OPV and NK 6410 live longer than male and female FAW, with female FAW living 10.40 d and male FAW living 9.13 and 9.20 d, respectively. FAW fed NK 6410 (GM) and Sweet Corn (Macho F1) had 100% survival, while FAW fed OPV, native corn (tinigib), and rice (RC 226) had 94.67, 94, and 88 % survival, respectively.

The number of egg masses significantly varied by food source. The number of egg masses in Corn- NK 6410 Corn (GM) and Sweet Corn (Macho F1) were significantly higher than those fed on native corn (tinigib), open-pollinated variety, and rice (Fig. 1). On the other hand, the highest fecundity was found on NK 6410 Corn, Macho F1, and OPV (Fig. 2).

DISCUSSION

Differences in the characteristics and quality of the host plants can have an impact on the life cycle of an insect, including its fecundity, ability to survive, and lifespan. (Awmack and Leather 2002). Plants that serve as hosts are the most important factor in determining how to control insect populations. (Umbarihowar and Hastings 2002). *S. frugiperda* host plants were summarized by Montezano et al. (2018), and a total of 353 plant species belonging to 76 families were recorded. This present study revealed that the result on the different life stages including number of eggs and egg masses of *S. frugiperda* were significantly different ($p < 0.05$) on the five plants tested. Many plant species deter oviposition and feeding in highly polyphagous insects (Hsiao and Fraenkel 1968).

Results of the study showed variations on the developmental time of *S. frugiperda* fed on different corn varieties and rice during the larval stage. The quality of the host plants have caused the significantly shorter duration of egg to adult in NK 6410 Corn (GM) and Sweet Corn (Macho F1) than the open-pollinated variety, native corn (Tinigib), and rice (RC 226). An extended egg-adult developmental time is thought to be a compensatory behavior that allows a larva to recover while feeding on a host plant with low nutritional quality while still pupating and gaining weight. In general, insect development and reproduction are influenced by the

Table 2. Sex ratio, longevity, and survivability (mean ± SD) of adult *Spodoptera frugiperda* fed with different corn varieties and rice.

Host Plant	Sex Ratio (%)		Longevity of Adults (days)		Survival (%)
	Female (N=5)	Male (N=5)	Female	Male	Larva-Adult
OPV Corn	49.33 ± 10.90[ns]	50.67 ± 10.90 [ns]	10.40 ± 0.60 [ns]	9.13 ± 0.69 [ns]	94.67 ± 8.69 [ns]
RICE (RC 226)	51.50 ± 11.67[ns]	48.50 ± 10.67 [ns]	9.80 ± 0.70 [ns]	8.80 ± 0.77 [ns]	88.00 ± 10.95 [ns]
Traditional Corn (Tinigib)	50.00 ± 11.32 [ns]	50.00 ± 11.31 [ns]	10.13 ± 1.02 [ns]	8.93 ± 1.14 [ns]	94.00 ± 8.40 [ns]
Corn- NK 6410 Corn (GM)	64.00 ± 5.48 [ns]	36.00 ± 5.47 [ns]	10.40 ± 0.86 [ns]	9.20 ± 0.38 [ns]	100 ± 0.00 [ns]
Sweet Corn (Macho F1)	60.00 ± 7.07 [ns]	40.00 ± 7.07 [ns]	9.98 ± 0.49 [ns]	9.07 ± 0.43 [ns]	100 ± 0.00

*Mean followed by the same letter in the column for each species did not differ statistically (Tukeys' HSD Test, $p \leq 0.05$).
ns = not significant

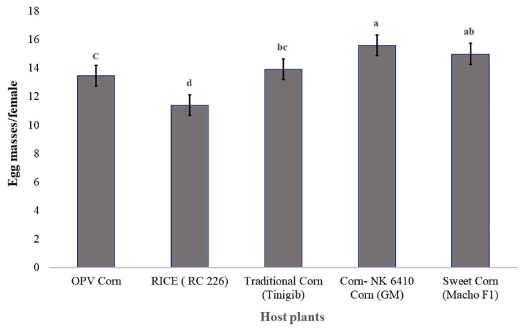

Fig. 1. Egg masses per female of *Spodoptera frugiperda* fed with different corn varieties and rice.

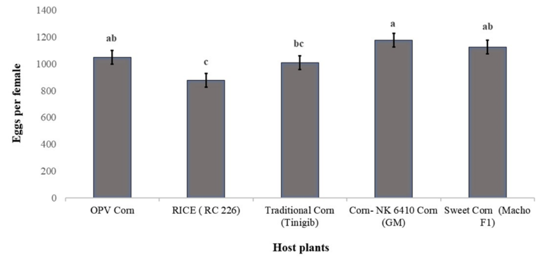

Fig. 2. Total eggs per female of *Spodoptera frugiperda* fed with different corn varieties and rice.

quality of food consumed during the first few instars that might differ depending on the host plants (Barros et al. 2010).

All plant species used in the study were grasses and belong to the family Poaceae. *S. frugiperda* can develop, survive, and reproduce in all these plant species, but there are differences in performance. The differences in traits and nutritional content of the different corn varieties and rice resulted in the differences in larvae, pupae, and adult longevity. The number of eggs and egg masses produced per female also differs among the plants tested. The performance of *S. frugiperda* in grasses has been demonstrated by Lewter et al. (2006), and Nagoshi et al. (2007). They reported that FAW had a good developmental performance in C4 plants like sorghum, bermudagrass, and corn, than soybean and cotton, which are C3 plants. This might be due to the nutritional content and composition of grasses which differs in other plant families (Barros et al. 2010). A higher number of eggs and egg masses produced per female in NK 6410 and Macho F1 than in OPV, Tinigib, and RC 226 was observed. Nutrient compositions are different on rice and corn varieties, and nutrient content, requirements, and have diversity. NK 6410 has BtGT traits for example, which is a combination of Bt11 x Ga21 and sh2 gene in Sweet Corn (Macho F1) (Singh et al. 2014), which changes these varieties' nutrient requirement and composition.

The amount and the quality of food accepted by the insect directly affect the development, reproduction, and survival of insects belonging to the order Lepidoptera (Golizadeh et al. 2009). Thus, to further assess the factors that influenced *S. frugiperda*, there is a need to identify the parameters that would help compare the nutritional quality of the different plant species (Scriber and Slansky 1981). Shorter time for feeding period, low mortality, and higher fecundity in polyphagous insects means a suitable developmental rate (Soo Hoo and Fraenkel 1966). This was shown in insects given NK 6410 and Macho F1. Despite its host suitability in NK 6410 and Macho F1, *S. frugiperda* has developed, lived, and reproduced in OPV, Tinigib, and RC 226. Therefore, damage of *S. frugiperda* population in these varieties and crop can also occur. Moreover, its ability to survive increases its population in the field. The result implied that *S. frugiperda* has a good chance of evolutionary survival in the long run since it has a wide spectrum of hosts to exploit. There is still a need to conduct studies that will look into the response of *S. frugiperda* to different food sources as it might give a different result.

The wide host range of *S. frugiperda* may have a greater impact on its migration to other crops. This in turn will have an influence on the management of this pest in general especially the use of insecticides. Adapting resistant cultivars will be able to be used simultaneously on different crops on the same area as an alternative in managing the pest. The selection pressure can be observed across crops in a comparable manner and can increase the genetic change (Herńandez-Marťinez et al. 2009). Moreover, the coexistence of different cultivar and crops in the same agroecosystem, especially corn and rice, could trigger the new host preference in the absence of the main host plant (Andrews 1980). In summary, the results on the life history of *S. frugiperda* showed that, in general, the development, survival, and reproduction were highly influenced by the quality of different host plant species. These results can be used in the development of an integrated management program for the control of economically important insect pests such as FAW.

CONCLUSION

The preference can be ranked as NK 6410 > Macho F1 > OPV > Tinigib > RC 226 based on the developmental time of larva, pre-pupa, and pupa, duration of oviposition period, total number of egg masses per female, and total number of eggs per female of *S. frugiperda*. The current study shown that *S. frugiperda* may develop and reproduce on rice and different corn varieties. These findings added to our understanding of the biology of *S. frugiperda*, which may aid in the development of alternative control strategies for this economically significant insect pest. Future research could include testing other plant species to have a better knowledge of *S. frugiperda's* development, survival, and reproduction. Furthermore, the chemical composition of different plant species should be investigated in order to better understand the host's compatibility.

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