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COMPARATIVE DEVELOPMENT OF *Spodoptera exempta* (Walker) (Noctuidae, Lepidoptera) ON *Zea mays* L. AND *Panicum maximum* Jacq. IN THE PHILIPPINES WITH NOTES ON ITS HOST RANGE, LARVAL FEEDING AND POST EMERGENCE BEHAVIOR OF ADULTS

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ABSTRACT

The development of the black armyworm *Spodoptera exempta* (Walker) on corn (*Zea mays* L) was compared with that on guinea grass (*Panicum maximum* Jacq.) under laboratory conditions at 27-28°C. Fifteen plant species consisting of 10 Graminae (=Poaceae) and one each of Convolvulaceae, Cucurbitaceae, Cyperaceae, Moringaceae and Musaceae were evaluated initially as potential hosts and for use as feed in the laboratory. Corn used as the standard host was the most severely fed upon followed by guinea grass (*Panicum maximum*) and torpedo grass (*P. repens*). Guinea grass was chosen over torpedo grass for the comparative biological studies with corn because the leaves of the former are bigger, thicker and would last longer under laboratory conditions when detached.

Spodoptera exempta **completed development on corn and guinea grass but significant differences were observed in the life history, fecundity and oviposition period related to larval host plant. Significant differences between males and females were also observed in total developmental period, adult longevity and size. The incubation period of the eggs ranged from 2 to 3 days, usually 2 days for both sexes. Development time for both sexes was significantly longer but oviposition period of females was significantly shorter on guinea grass than on corn. The number of egg masses laid by females ranged from 2 to 6 ($\bar{X}$=4.70 ± 1.16) with total number of eggs ranging from 412 to 1,318 ($\bar{X}$=834.80 ± 293.99) on corn compared to 1 to 5 ($\bar{X}$=2.50 ± 1.31) egg masses and 147-774 ($\bar{X}$=398.50 ± 231.50) total number of eggs on guinea grass.**

Key words: black army worm, *Spodoptera exempta*, comparative biology, host plants, corn, *Panicum maximum* and *P. repens*

INTRODUCTION

In the Philippines, the recent outbreak of the black armyworm, *Spodoptera exempta* (Walker), in major crop-growing areas alarmed farmers and government agencies. Although it has long been reported as a pest of crops in the country along with several species belonging to the genus *Spodoptera* (Gabriel 2000), its recent outbreak indicates its potential to become a recurring pest and may have major impact on cereal and livestock production in the country. With its rapid development, high reproductive capacity, and mobility by migration, *S. exempta* is well adapted to exploit the highly seasonal and ephemeral habitats provided by the rain-induced growth of host plants (Rose et al., 1996).

S. exempta is a major episodic migratory crop pest in Eastern and Southern Africa (Grzywacz et al., 2008). It is also reported in the Arabian Peninsula, and in Southeast Asia, Australasia and Oceania (including Hawaii, USA). In Southeast Asia, it is most frequently recorded in the Indonesian islands, including Kalimantan and Sulawesi and in the Philippines. In Australasia, it is confined to Papua New Guinea, the Solomon Islands and New Caledonia, and to the northern and eastern seaboard of Australia.

In nature, *S. exempta* larva feeds primarily on plants belonging to the families Graminae (=Poaceae) and Cyperaceae including those of major economic importance: corn, rice, sorghum, sugarcane, wheat and pasture grasses, especially *Cynodon* and *Pennisetum* species. The larvae exhibit strong host preferences for species within Graminae (=Poaceae) and there are major differences among varieties of cereal crops in their susceptibility to attack. Rose et al. (1996, 2000) made a list of wild and cultivated host plants of *S. exempta*. Generally, these plants may contain different sugars and carbohydrates, starch, glucose, sucrose and fructose (Creech, 1968), proteins, lipids, minerals and vitamins (Tabashnik and Slansky 1987) which could affect growth and reproduction of insects. Ahmad and Kamal (2001) showed that sucrose, fructose, glucose, and maltose strongly stimulated feeding, while mannitol did not stimulate feeding of last instar larvae of *S. exempta*. Schiff et al (1989) earlier showed that mannitol is nutritive but not phagostimulatory to *Heliothis zea*.

S. exempta larvae develop in markedly different color forms with associated behavioral peculiarities referred to as 'phase polyphenism' depending on larval densities in the early instars (Rose et al., 1996; 2000). Although similar phase polyphenism occurs in other Noctuidae, it is most strongly developed in *S. exempta*, in which the highly conspicuous, heavily pigmented and active 'gregarious' ('gregaria') form, typical of outbreak populations, is the familiar armyworm. The cryptic, sluggish 'solitarious' ('solitaria') form, typical of low-density populations, is difficult to find and often not recognized as *S. exempta*.

Despite its common occurrence, very little is known about the life cycle, feeding habits, mating behavior and host range of *S. exempta* in the Philippines, except for the limited information from the undergraduate thesis of Rimando (1954) which has remained unpublished up to the present. The present authors were able to collect samples from a remnant outbreak population in Sariaya, Quezon last August 2010.

Hence, this study was conducted to determine some important biological parameters such as life history, behavior and description of the different developmental stages, feeding behavior, adult emergence pattern, mating behavior, female fecundity, pre-oviposition, oviposition, and post oviposition periods, adult longevity in relation to food source, sex ratio and potential host plants of *S. exempta*. Phase polyphenism in this species will be dealt with separately. The information generated may contribute greatly to better understanding of outbreak occurrence and help in forecasting, if not preventing, recurring outbreaks in the future.

MATERIALS AND METHODS

Stock culture of *S. exempta*

The starting live specimens for the laboratory stock culture of *S. exempta* were collected from a remnant outbreak population in Sariaya, Quezon in August 2010. The field-collected larvae were placed in plastic containers, brought to the laboratory for rearing, fed with detached leaves of corn (*Zea mays*) and Johnson grass (*Sorghum halepense* L.), and allowed to pupate on moist coir dust in a glass cage for adult emergence. The oviposition substrate offered consisted of detached shoots of Johnson grass. Adults were fed with 10% sucrose. Rearing conditions were 27-28 °C and 70-90% relative humidity. The *S. exempta* larvae used as experimental test insects were taken from the mentioned stock culture maintained in the National Crop Protection Center, Crop Protection Cluster, University of the Philippines Los Baños, College, Laguna, Philippines.

Host range and selection of food plants for *S. exempta*

Corn, seven weeds and two ornamental species representing the Graminae (=Poaceae) were evaluated as potential larval hosts for rearing *S. exempta* under laboratory conditions. Representative species of Convolvulaceae, Cucurbitaceae, Cyperaceae, Moringaceae and Musaceae were also included to verify published information (Rose et al. 1996, 2000) that host range of *S. exempta* is limited to the Graminae (=Poacea) and Cyperaceae.

Seeds of corn were sown in the greenhouse at the National Crop Protection Center. Detached young leaves from 2-week old seedlings, embedded on moist cotton balls in plastic cups were offered to the experimental insects. Apical soft green leaves of the selected plants were collected from different sites in the Central Experiment Station of the College of Agriculture, University of the Philippines Los Baños and offered to the test insects in the same manner as corn. Five each of 1day-old, 3d-old, 5d-old, 7d-old and 9d-old larvae of *S. exempta* were allowed to feed for 24h separately on each host plant, with corn as standard for comparison. Extent of feeding was rated visually using the following scale: – = zero feeding, + = slight feeding, ++ = moderate feeding, and +++ = extensive feeding. To ensure a homogenous population of test larvae, the specific age group came from a single egg mass and the tests were done simultaneously within 24h.

Corn and guinea grass (*Panicum maximum* Jacq.) which were found as the more suitable feeding materials were used then in maintaining the stock culture and in the comparative development studies conducted.

Life History

Egg masses laid on the same day were collected from the stock culture by clipping portions of leaves containing them, placed separately in big test tubes for holding and incubation, and provided with fresh detached corn leaf/guinea grass as food for the larvae. Several egg masses laid within 24h by the confined females were selected and observed closely and continuously to record hatching behavior and incubation period.

Using a camel's hair brush, two sets of fifty newly hatched larvae were transferred to transparent plastic plates measuring 8.5 cm diameter and 1.5 cm high, placing one larva in each (Figure 1). One set was fed with corn and the other with guinea grass. New rearing plates were prepared for larval transfer until life history studies were completed. The cultures were observed daily to record the durations of the different larval instars.

When mature larvae stopped feeding the rearing plastic plates were cleaned of uneaten food and frass in preparation for pupation. Pupal period and adult longevity were also recorded.

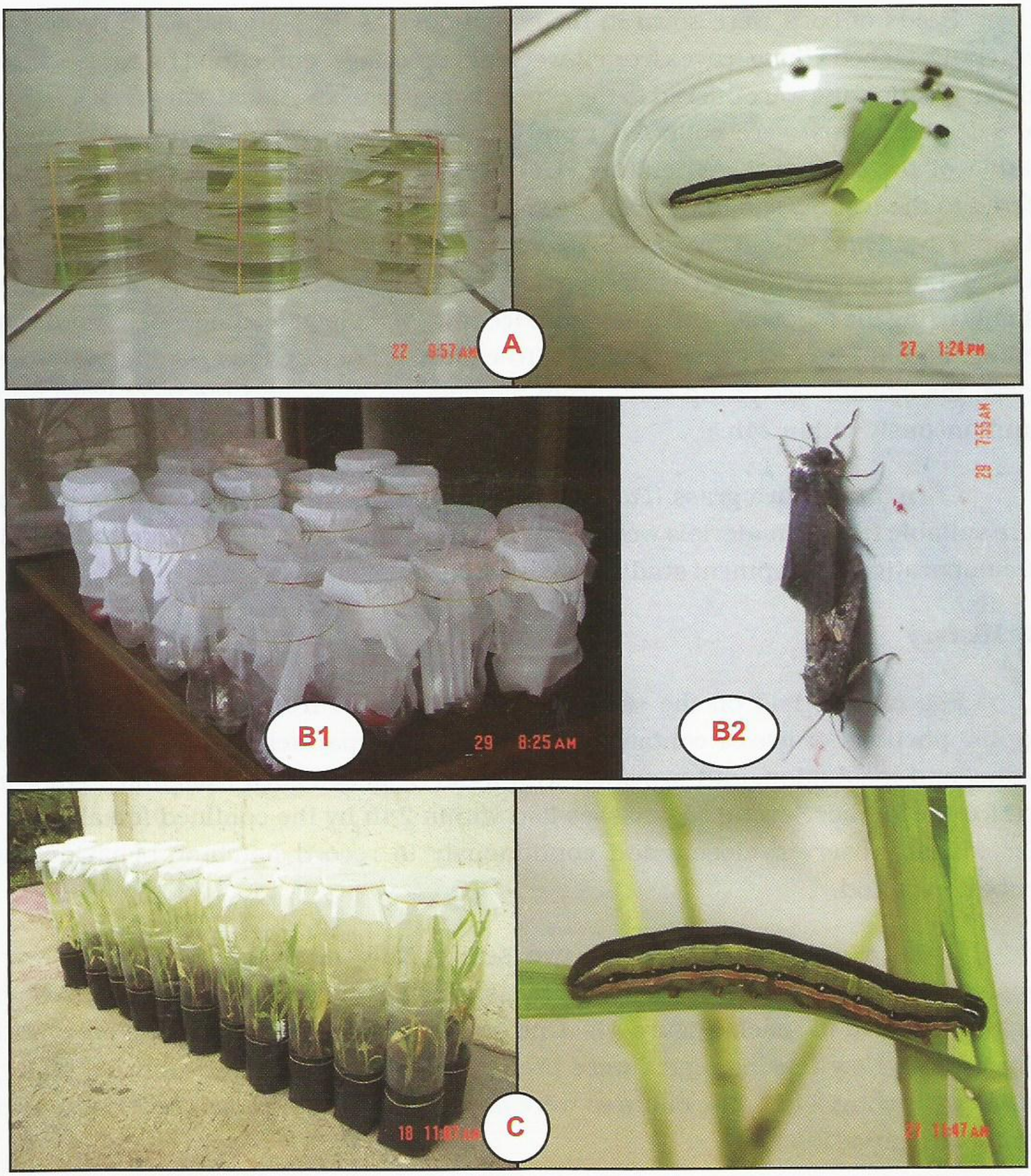

Figure 1. Rearing units used for laboratory culture of *Spodoptera exempta*: (A) rearing plates, (B1) improvised oviposition containers using 1.5L plastic bottles, each containing (B2) one male and one female adults and (C) potted corn seedling with a larva and covered with rolled thick plastic sheet.

Effect of food source on fecundity and adult longevity

Ten pairs each of newly emerged adults reared on corn and on guinea grass were offered 10% sugar solution as food/moisture source. Another two sets of 10 pairs each were prepared simultaneously, one set provided with water as moisture source, and the other kept without moisture source. When copulation was observed, the oviposition substrate (leaf of *P. maximum*) was searched thoroughly twice a day for egg masses. The total number of egg masses and number of eggs per egg mass laid per female in her lifetime were computed. Data on longevity of female and male adults were taken from this set-up.

Hatchability:

Egg masses (from females not used in the fecundity test) were kept properly embedded in test tubes. The number of newly hatched larvae was recorded to determine the number of eggs hatched per egg mass. The newly hatched larvae were then placed in plastic pans for further rearing.

Feeding behavior:

Two weeks old corn seedlings (var. Lagkitan) were placed individually in 20 plastic cages, each cage infested with a newly hatched larva of *S. exempta* placed at the base of the plant, and observed closely for larval movement, feeding site selection and feeding behavior until completion of larval development.

Pupation:

The larvae from the life history studies and those released individually on potted corn seedlings were reared continuously till completion of larval development and then pupation behavior was observed.

Adult emergence pattern:

About 150 pupae of *S. exempta* collected from the stock culture were placed in a zip-locked big plastic cage for adult emergence. The time from the first up to the last adult emergence was recorded at hourly interval for 24h, taking out promptly the emerged adults and recording the sex.

RESULTS AND DISCUSSION

Selection of food plants for *S. exempta*

Fourteen out of the 15 plant species tested as potential larval hosts of *S. exempta* were fed upon by the larvae at various instars (Table 1). However, only six graminaceous species; namely, corn, guinea grass, torpedo grass, carabao grass, napier grass and wire grass, were fed upon by all larval age groups and extensively fed upon particularly by older larvae representing the later instars. Although all larval age groups fed on tigbi, the degree of feeding was slight even for the later instars. The other Graminae, (two bamboo species and cogon) have thick and rough leaves that appear to be not suitable feeding substrates particularly for the young larvae. The results suggest that under natural condition the insect may be able to complete its development on the six graminaceous species evaluated.

Table 1. Plants tested as potential larval hosts and feeding damage of *Spodoptera exempta* larvae at different ages after 24h feeding access period.

Host Plant			Larval Age (in days) and Degree of Damage Inflicted*				
Common Name	Scientific Name	Family	1	3	5	7	9
Corn	*Zea mays L.*	Graminae (=Poaceae)	+	+	++	+++	+++
Guinea grass	*Panicum maximum Jacq.*	Graminae (=Poaceae)	+	+	+	++	+++
Torpedo grass	*Panicum repens L.*	Graminae (=Poaceae)	+	+	+	++	+++
Carabao grass	*Paspalidium flavidium Retz.*	Graminae (=Poaceae)	+	+	+	++	++
Napier grass	*Pennisetum purpureum Schumach.*	Graminae (=Poaceae)	+	+	+	++	++
Wire grass	*Cynodon dactylon (L.) Pers.*	Graminae (=Poaceae)	+	+	+	+	++
Buddha's belly bamboo	*Bambusa ventricosa McClure*	Graminae (=Poaceae)	-	+	+	++	++
Dwarf white striped bamboo	*Pleioblastus variegatus (Siebold. ex Miq.) Makino*	Graminae (=Poaceae)	-	-	+	++	++
Tigbi	*Coix lacryma L.*	Graminae (=Poaceae)	+	+	+	+	+
Cogon	*Imperata cylindrica (L.) Beauv.*	Graminae (=Poaceae)	-	-	+	+	+
Purple nutsedge	*Cyperus rotundus L.*	Cyperaceae	+	+	+	+	+
Sweet potato	*Ipomea batatas (L.) Lam.*	Convolvulaceae	+	+	+	+	+
Banana	*Musa sapientum L.*	Musaceae	+	+	+	+	+
Patola	*Luffa acutangula L.*	Cucurbitaceae	-	+	+	-	-
Horseradish tree	*Moringa oleifera Lam.*	Moringaceae	-	-	-	-	-

*(-) = no feeding damage, (+) = slight feeding damage, (++) = moderate feeding damage, (+++) = severe feeding damage

S. exempta has been reported to have special preference for graminaceous plants (Rose et al, 1996). Although feeding was observed on some other plants belonging to other families, the damage was minimal, suggesting that the insect was just forced to feed under confinement. Similarly, the rest of the plants tested can be considered non- hosts. Considering that even among major cereal crops different varieties exhibit differences in their susceptibility to attack of *S. exempta*, (Rose et al, 1996, 2000) inclusion of family Cyperaceae in the host range of *S. exempta* may be questionable.

Among the six grasses that were readily accepted by the larvae, only two species (guinea grass and torpedo grass) were as equally accepted as the standard host plant corn. Consequently, guinea grass was chosen as a larval host plant in the comparative biological study because the leaves are bigger and thicker, thus lasted longer than *P. repens* under laboratory conditions when detached.

Life history of *S. exempta*

Description of developmental stages. Like other species of *Spodoptera* studied in the Philippines, *S. exempta* passes through the egg, six larval instars, pupal and adult stages. The characteristics of different stages were based on actual observations of live individuals and alcohol preserved specimens.

Egg (Fig.2A). Eggs are covered with black hair scales from the tip of the female's abdomen. Newly laid eggs are smooth, yellowish white or pale, globose, measure from 0.39 to .70 mm in diameter. The eggs darken during development until just before hatching, when the black head capsules of the larvae can be seen through

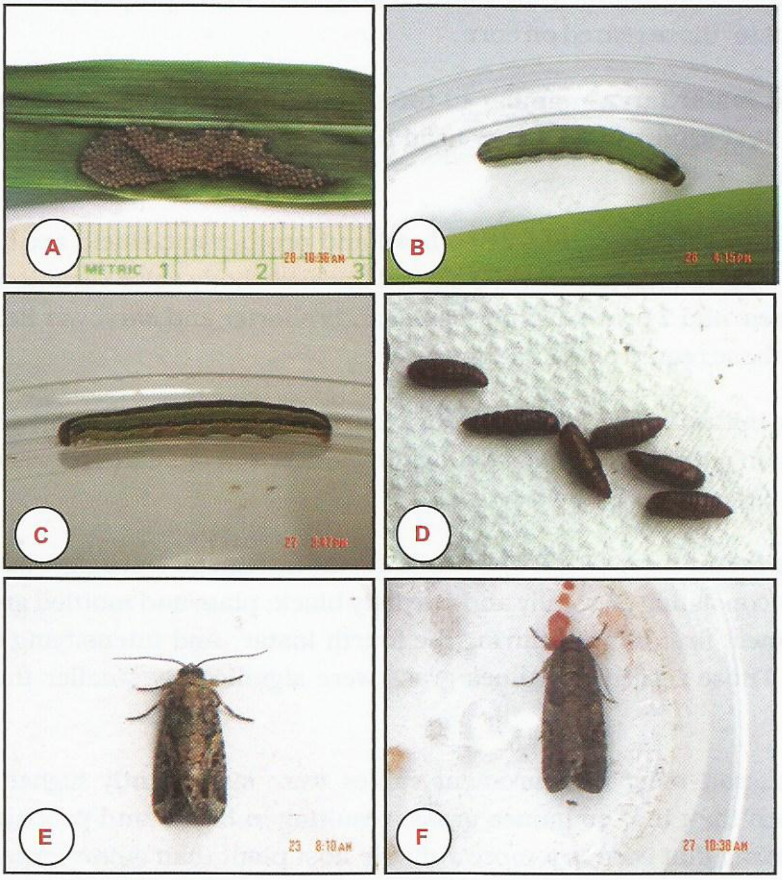

Figure 2. Developmental stages of *Spodoptera exempta*: (A) egg mass, (B) about to molt 4[th] instar larva, (C) 6[th] instar larva, (D) pupae, (E) adult male and (F) female.

the chorions. Generally, eggs laid by females that fed on corn in the larval stage were slightly bigger than those by females reared on guinea grass. This may have implication on hatchability and survival of larvae in the field. Furthermore, female moths ensuing from larvae reared on corn had higher fecundity.

First instar larva– elongate- cylindrical, green with black head when seen under the microscope but appeared black to the naked eye because of long body hairs; black prothoracic shield. Larvae aggregated on the site where the eggs were laid but dispersed later and moved towards the direction of sunlight and feed; with 3 pairs of legs, 4 pairs of body prolegs and a pair of anal prolegs; first instar larvae reared on guinea grass had significantly wider head capsule but shorter and narrower body than those that fed on corn.

Second instar larva– remained green but bigger; dorsal line prominently white with 3 white bands below; bases of body hairs distinct and brown. Those that fed on guinea grass had significantly shorter body but with comparable head capsule measurement to those reared on corn.

Third instar larva– similar to the second instar but bigger; those reared on guinea grass had significantly longer head but shorter and narrower body than those reared on corn.

Fourth instar larva (Fig. 2B)– head and prothoracic shield are black; shield with 3 white longitudinal and 2 white curved lines; six body color variations observed: 2 black, 2 green and 2 brown forms; significantly shorter and narrower head and body observed on those reared on guinea grass.

Fifth instar larva– similar to the fourth instar but bigger and color darker; those reared on guinea grass had significantly longer but smaller and narrower head; shorter body than those reared on corn.

Sixth instar larva (Fig. 2C)– similar to the fifth instar but bigger and with more varied colors consisting of: totally and partially black; plain and mottled green; brown and dark brown, first noticed during the fourth instar and intensifying towards the sixth instar. Those reared on guinea grass were significantly smaller than those on corn.

In general, most measurement values were significantly higher for the set reared on corn than that on guinea grass, resulting in bigger and probably healthier larvae, indicating that corn is a more suitable host plant than guinea grass. Healthier larvae could mean bigger adults with greater reproductive capacity and greater potential for population increase, thus likely to result in more damage to crops.

Pupa (Fig. 2D) – obtect pupa initially greenish, turning brown within a day, to black on day of adult emergence. Those reared on guinea grass during the larval stage were significantly smaller than those on corn (Table2).

Adult (Fig. 2E-F) – moth grayish brown with distinctive gray-black markings; two white spots on forewings; inner spot, elongate and pale; outer spot, kidney-shaped, more clearly visible in males than in females; hindwings pale white with dark veins; female with more intense color than male; abdomen covered with pale gray-brown scales; tip of female abdomen with black hair-scales.

Adults may be distinguished from other *Spodoptera* spp. by their forewing patterns and genitalia using keys published by Brown and Dewhurst (1975) and modified by Rose et al. (1996). The black hair-scales at the tip of female moth abdomen and the gray, racket-shaped scales on the outer part of the male genitalia, are characteristic of S. *exempta*, and useful in identifying moths which have lost their wing scales, e.g. in light traps (Rose et al. 1996).

The lengths of body and antenna, and wing expanse of the male and female did not differ significantly between adults that emerged from larvae fed with corn and from those fed with guinea grass (Table 2). However, the female has a shorter body and antenna than the male but with wider wing expanse.

Durations of developmental stages. The durations of the different developmental stages of *S.exempta* reared on corn and guinea grass are shown in Tables 3a & b. The incubation periods are the same on the two host plants. All eggs in the mass or cluster hatched within 2-3 days which is typical of member species of *Spodoptera.* The durations of the six larval stadia were not significantly different between male and female that fed on the same host plant. However, variations existed between sexes of individuals reared on the two hosts, hence, data were analyzed for males and females separately using t-test. Starting from the fourth larval instar, significantly shorter developmental periods were observed in the male individuals that fed on corn (Table 3a). However, significantly shorter developmental periods were observed in the female individuals that fed on corn only on the fourth and sixth instars (Table 3b). Expectedly, total larval period was significantly shorter by three days for males that fed on corn. However, although larval period was significantly shorter for females reared on the former host, the difference was only two days. Pupal period was, likewise, significantly shorter for males reared on corn but for females, pupal periods were similar on the two host plants. In general, total developmental period (egg to adult) was significantly shorter for individuals reared on corn regardless of sex. Faster rate of development on corn translates to shorter generation time.

Table 2. Measurements (mm) of pupa and adult *Spodoptera exempta* (Walker) reared singly on corn and guinea grass.

STAGE	PARAMETER	RANGE		MEAN	
		Corn	Guinea Grass	Corn	Guinea Grass
Pupa	Length	12.00-14.00	10.00-14.00	13.45 ± 0.60a	12.30 ± 1.16b
	Width	4.00-4.55	3.75-4.50	4.19 ± 0.17a	4.06 ± 0.22a
Adult	Length of Body	12.00-15.00	11.00-14.50	13.55 ± 1.01a	13.10 ± 1.15a
Male	Wing Expanse	26.00-32.00	26.00-32.00	28.80 ± 1.75a	28.50 ± 2.12a
	Length of Antenna	7.50-8.00	7.00-8.00	7.85 ± 0.24a	7.70 ± 0.35a
Adult	Length of Body	11.00-14.50	11.00-14.50	12.95 ± 1.21a	12.90 ± 1.10a
Female	Wing Expanse	25.00-34.00	26.00-32.00	30.60 ± 2.67a	28.90 ± 1.85a
	Length of Antenna	6.75-8.75	7.00-8.00	7.78 ± 0.58a	7.65 ± 0.34a

*Means in a row followed by a common letter are not significantly different at 5% level of significance.

Table 3a. Durations (days) of the different stages of male *Spodoptera exempta* (Walker)reared on corn and guinea grass leaves under laboratory conditions.

DEVELOPMENTAL STAGE	RANGE		MEAN	
	Corn	Guinea Grass	Corn	Guinea Grass
Egg Incubation	2-3	2-3	2.5	2.5
Larva				
First Instar	1-2	1-2	1.06 ± 0.24a	1.10 ± 0.31a
Second Instar	1-2	1-2	1.12 ± 0.33a	1.32 ± 0.48a
Third Instar	1-2	1-2	1.06 ± 0.24a	1.10 ± 0.31a
Fourth Instar	2-3	2-3	2.12 ± 0.33a	2.42 ± 0.51b
Fifth Instar	2-3	2-3	2.12 ± 0.33a	2.84 ± 0.60b
Sixth Instar	3-5	3-5	3.18 ± 0.53a	4.32 ± 0.82b
Total Larval Period	11-15	12–16	11.76 ± 1.20a	14.95 ± 1.39b
Pupa	5-6	5–8	5.88 ± 0.33a	6.53 ± 0.70b
Total Developmental Period	18-23	20-26	19.65 ± 1.11a	23.47 ± 1.87b

*Means in a row followed by a common letter are not significantly different at 5% level of significance.

Table 3b. Durations (days) of the different developmental stages of female *Spodoptera exempta* (Walker) reared on corn and guinea grass leaves under laboratory conditions.

DEVELOPMENTAL STAGE	RANGE		MEAN	
	Corn	Guinea Grass	Corn	Guinea Grass
Egg Incubation	2-3	2-3	2.5	2.5
Larva				
First Instar	1-2	1-2	1.04 ± 0.20a	1.15 ± 0.38a
Second Instar	1-2	1-2	1.12 ± 0.34a	1.23 ± 0.44a
Third Instar	1-2	1-2	1.12 ± 0.34a	1.23 ± 0.44a
Fourth Instar	2-3	2-3	2.17 ± 0.38a	2.54 ± 0.52b
Fifth Instar	2-3	2-3	2.21 ± 0.41a	2.39 ± 0.51a
Sixth Instar	3-5	3-5	3.29 ± 0.46a	4.00 ± 0.82b
Total Larval Period	11-13	12-16	12.08 ± 0.78a	14.15 ± 1.16b
Pupa	5-6	5-7	5.25 ± 0.44a	5.69 ± 0.85a
Total Developmental Period	18-21	19-25	19.33 ± 0.87a	21.85 ± 1.95b

*Means in a row followed by a common letter are not significantly different at 5% level of significance.

Table 4. Post developmental periods (days) of female *Spodoptera exempta* (Walker) reared on corn and guinea grass leaves under laboratory conditions.

POST DEVELOPMENTAL STAGE	RANGE		MEAN	
	Corn	Guinea Grass	Corn	Guinea Grass
Pre-oviposition	2-3	2-3	2.32 ± 0.48a	2.33 ± 0.49a
Oviposition	1-6	1-5	4.70 ± 1.16b	2.50 ± 1.31a
Post-oviposition	1-5	1-5	1.87 ± 1.06a	1.73 ± 1.28a

*Means in a row followed by a common letter are not significantly different at 5% level of significance.

The post developmental period of *S. exempta* typically consisted of three phases, namely; pre-oviposition, oviposition and post oviposition (Table 4). The oviposition phase was the longest among the three on both host plants, although the difference was significant only for females that fed on corn during the larval stage.

Effect of larval food source on fecundity

The number of egg masses laid per female (2-6) and total number of eggs per female (412-1,318) varied significantly between corn and guinea grass as larval feed (Table 5). Notably, the number of eggs per egg mass for the first batch of eggs was significantly higher for adults reared on corn. The 2nd to the 4th batches of egg masses were likewise consistently bigger, although the difference was insignificant. The 5th and 6th batches of egg masses were smaller and mostly did not hatch. This means that adults emerging in corn fields have greater potential to lay more eggs in a wider area and greater damage potential of the larvae produced than those emerging from grasslands with guinea grass as a dominant weed. The present study revealed that corn is superior to guinea grass as food plant for *S. exempta* where larval duration was shorter, growth rate was higher, adult lifespan longer and fecundity greater. The nutrition from guinea grass might be inadequate, resulting in growth retardation, late maturation and shorter adult life span.

However, depending on the availability of particular food plants in various localities, *S.exempta* may shift from one host plant to another. Reports showed that mixed plant diets are superior for certain species of insects by promoting higher survival, larger adults and higher growth indices than any single plant diet (Bernays

Table 5. Fecundity of *Spodoptera exempta* (Walker) reared individually under laboratory conditions as affected by larval host plant.

FECUNDITY	RANGE		MEAN	
	Corn	Guinea Grass	Corn	Guinea Grass
No. of egg mass per female	2-6	1-5	4.70 ± 1.16b	2.50 ± 1.31a
No. of eggs per female	412-1318	147-774	834.80 ± 293.99b	398.50 ± 231.50a
No. of eggs per egg mass				
First batch	129-587	6-288	394.80 ± 152.42b	166.13 ± 84.73a
Second batch	41-341	87-325	214.90 ± 88.45a	187.00 ± 98.41a
Third batch	81-334	86-181	152.22 ± 76.58a	144.50 ± 41.06a
Fourth batch	23-159	0-79	74.11 ± 41.27 b	7.9a
Fifth batch	2-43	0-80	24.00 ± 15.96b	8.0a
Sixth batch	11-35	0	23.00 ± 16.97b	0.0a

*Means in a row followed by a common letter are not significantly different at 5% level of significance.

and Bright, 1991; Fanny et al., 1999). Hence, it is evident that adequate diet is expected to reduce larval developmental period, which is very important for the fitness and survival of the insect (Price et al., 1980).

Effect of available food on adult survival

Adult survival was longest for those fed with 10% sugar solution and shortest for those without source of moisture for the group reared on corn in the larval stage (Table 6). There was a slight difference between sexes in favor of the males. Adult males lived for about 8 days in 10% sugar solution, 6 days on water only and 3 days with no moisture source in corn fed groups. Lifespan of adult females on 10% sugar solution was about 7 days, about 6 days on water only, and about 3 days without moisture source in corn fed group. Adults from the group that fed on guinea grass in the larval stage lived as long as the females from group that fed on corn.

Table 6. Comparative lengths of survival of male and female *Spodoptera exempta* (Walker) adults from larvae reared on corn when the moths were kept in cages with or without food source.

FOOD/MOISTURE SOURCE	SURVIVAL PERIOD (NO. OF DAYS)			
	RANGE		MEAN	
	Male	Female	Male	Female
10% sugar solution	6-10	5-8	8.18 ± 1.54b	6.89 ± 1.27a
water only	3-9	5-7	5.60 ± 1.90a	6.00 ± 0.67a
No food source	3-4	2-4	3.37 ± 0.52a	3.28 ± 0.76a

*Means of the same sex in a row followed by a common letter are not significantly different at 5% level of significance.

The short adult lifespan due to lack of moisture source did not allow females from corn-fed larvae to lay the 3rd to 6th batches of eggs. To support the requirement for mating and reproduction both sexes must have access to water at the least. In females, the oocytes are not yet developed when the moths emerge, but develop to approximately half full size within 24 h (Rose et al., 1996). When reproductive development is completed in about three days after emergence, the female releases sex pheromone to attract a male mate to fertilize the eggs, and water is necessary to hydrate the maturing oocytes. In the wild where nectar is available, moths feed voraciously on it or drink dew.

The results showed that larval host plant and adult food source are significant factors that may directly affect the developmental period, adult survival and fecundity, and may contribute to the development of outbreak population.

Observations on Habits and Behavior

Egg Hatching. The eyes of the developing embryo were clearly visible by the end of the 2nd day from oviposition. Hatching started with the chorion bursting above the head of the embryo. A few minutes later, the young larva had its body entirely out of the shell. Normally, all eggs in a batch hatched within a few minutes.

Insect Feeding. Newly hatched larvae were observed feeding on areas between leaf veins, usually from the tip of the leaf downwards whether attached or detached from the plant. Once feeding commenced, the insect tended to concentrate on this feeding area until papery spots began to appear on the leaf surface. A single larva could consume three 5-leaf stage corn seedlings to complete development.

Molting. A day before molting, the larvae stopped feeding with their bodies markedly shortened and thinner. Molting started with the splitting of the old head capsule posteriorly down to the prothorax and abdomen. By regular peristaltic-like movement from the head, the old integument got released and the legs and all parts of the body freed from the old integument. The molting process took about 5-10 minutes; newly molted larva remained close to the exuvia which was eaten eventually.

Pupation. The mature larva when about to pupate stopped feeding and moved around the rearing plate in search of pupation site among uneaten leaves or frass. It became distended and then contracted before finally molting to the pupal stage. On potted corn plants, the mature larva burrowed into the soil and pupated in earthen chambers 2 to 3 cm below the surface.

Adult emergence (Fig. 3). The emergence pattern of laboratory-reared adults of *S. exempta* shows that the moths emerged in the early part of the night. About 69% emerged between 6:00 and 11:00 pm but peak of emergence was between 7:00 and 8:00 pm, approaching the time reported by Rose et al. (1996) for the same species (Figure 3). At the peak of emergence, 22% of emerged adults consisted of about 64% males and 36% females. The earliest time observed when the first adult emerged was between 2:00 and3:00 pm and the last at about 8:00 to 9:00 am. The adults were more active at night, although they were also observed flying, feeding on sugar solution, mating and laying eggs during the latter part of the day.

Courtship and Mating. Courtship was observed in *S. exempta,* initiated by the male by tapping its antennae back and forth until they reached the female. A receptive female also tapped its antennae back and forth, touching the male's antennae. The male mounted on the female, shortly assuming a posterior to posterior position. Mating occurred at anytime of the day, but mostly at dusk. Copulation lasted for a few minutes to about an hour. When disturbed, they moved away separately but mated again later. Multiple mating was observed but single mating was enough for the female to lay fertile eggs. In the breeder cage, breeding pairs were observed mating within a day after emergence.

Oviposition. Oviposition occurred less than one day after copulation. The female remained stationary when laying eggs. In the breeding cultures, females usually laid eggs after the 3rd day of emergence at night time. Under laboratory condition, it took the female a few hours to lay all the eggs in clusters or masses arranged in single or multilayers. For egg laying substrate, the female used the walls of the plastic bottle, muslin cloth/paper towel cover, or leaves of larval host plant. This is consistent with the observations that *S. exempta* does not have preferred oviposition host. In the field, eggs may be laid on trees, wooden or concrete posts, walls of houses and other structures. The female covers the eggs with black hair scales from the tip of its abdomen. Usually, egg masses laid in the later part of the reproductive period have fewer eggs or thinner scale covering.

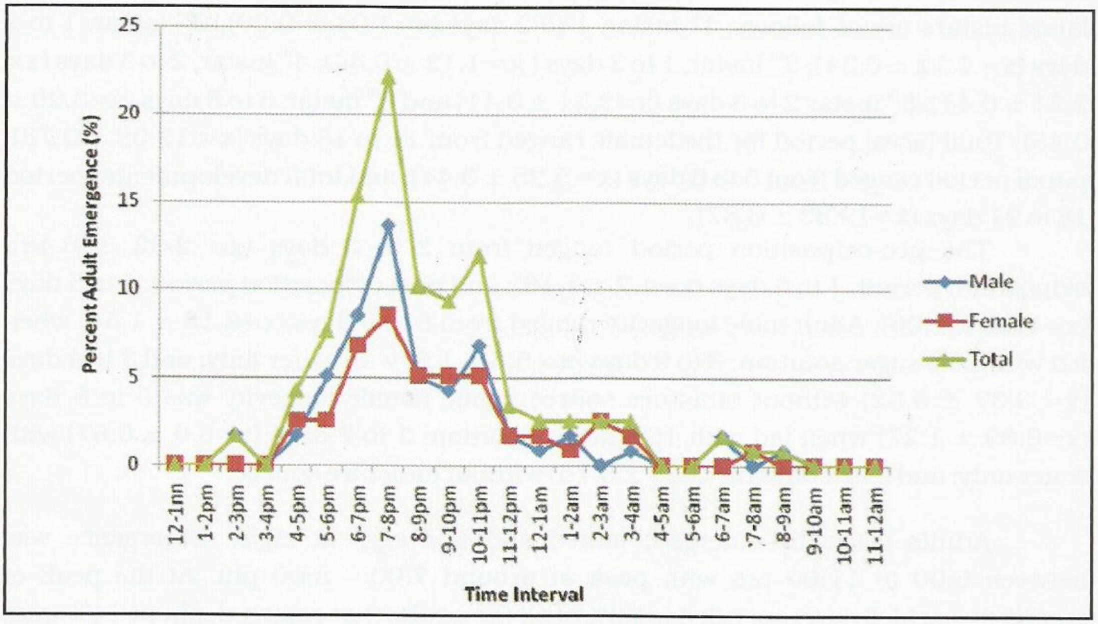

Figure 3. Pattern of emergence of *Spodoptera exempta* (Walker) adults from 150 pupae observed continuously for 24 hours in the laboratory.

SUMMARY AND RECOMMENDATION

Fourteen of 15 plant species tested as larval hosts were fed upon by *Spodoptera exempta* (Walker); 9 species belonging to family Graminae (=Poaceae) were accepted by the test larvae, 2 of which as equally as corn. Guinea grass was chosen as a larval host plant in the biological study because the leaves are bigger, thicker and lasted for about three days under laboratory conditions when detached.

The development, feeding habits, host plants, adult emergence pattern of *S. exempta* on corn and guinea grass were studied in the laboratory.

S. exempta passed through the egg, six larval instars, pupal and adult stages. Significant differences in the life history, fecundity, longevity and oviposition period were observed related to larval rearing host plant and adult food.

The incubation period of the eggs ranged from 2 to 3 days, usually 2 days. On corn, the duration of the male larval instars are as follows: 1^{st} instar, 1 to 2 days (x=1.06 ± 0.24); 2^{nd} instar, 1 to 2 days (x= 1.12 ± 0.33); 3^{rd} instar, 1 to 2 days (x= 1.06 ± 0.24); 4^{th} instar, 2 to 3 days (x= 2.12 ± 0.33); 5^{th} instar 2 to 3 days (x=2.12 ± 0.33) and 6^{th} instar, 3 to 5 days (x=3.18 ± 0.53). Total larval period for the male ranged from 11 to 15 days (x= 11.76 ± 1.20); pupal period 5 to 6 days (x= 5.88 ± 0.33); and total developmental period 18 to 23 days (x= 19.65 ± 1.11). The duration of the female larval instars are as follows: 1^{st} instar, 1 to 2 days (x=1.04 ± 0.20); 2^{nd} instar, 1 to 2 days (x= 1.12 ± 0.34); 3^{rd} instar, 1 to 2 days (x= 1.12 ± 0.34); 4^{th} instar, 2 to 3 days (x= 2.21 ± 0.41); 5^{th} instar 2 to 3 days (x=2.21 ± 0.41) and 6^{th} instar, 3 to 5 days (x=3.29 ± 0.46). Total larval period for the female ranged from 11 to 13 days (x= 12.08 ± 0.78); pupal period ranged from 5 to 6 days (x= 5.25 ± 0.44); and total developmental period 18 to 21 days (x=19.33 ± 0.87).

The pre-oviposition period ranged from 2 to 3 days (x= 2.32 ± 0.48); oviposition period, 1 to 6 days (x=4.7 ± 1.16); and post oviposition period, 1 to 5 days (x=1.87 ± 1.06). Adult male longevity ranged from 6 to 9 days (x=8.18 ± 1.54) when fed with 10% sugar solution; 3 to 9 days (x= 5.6 ± 1.9) with water only; and 3 to 4 days (x= 3.37 ± 0.52) without moisture source; while female longevity was 5 to 8 days (x=6.89 ± 1.27) when fed with 10% sugar solution; 5 to 7 days (x=6.0 ± 0.67) with water only; and 2 to 4 days (x=3.28 ± 0.76) without moisture source.

Adults generally emerged, mated and laid eggs at night. Emergence was between 6:00 to 11:00 pm with peak at around 7:00 – 8:00 pm. At the peak of emergence, which corresponded to 22% of all the adults that emerged, about 14% were males and 8%were females. The earliest time an adult emerged was between 2:00 to 3:00 pm and the last at about 8:00 to 9:00 am.

Follow up study should be conducted to determine the difference in rate of development between those reared singly and in group as well as those of the offspring of solitary and gregarious populations. Long term study on population dynamics should also be conducted to identify other conditions useful in developing model(s) for predicting potential occurrence of outbreaks to lessen, if not avoid completely, the consequential economic damage to crops.

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LITERATURE CITED

AHMAD I & M KAMAL. 2001. Consumption and utilization of complete defined diets of various carbohydrates by *Spodoptera exempta* (Lepidoptera:Noctuidae). Biota 6(3): 99-104.

BERNAYS, E A & K BRIGHT. 1991. Dietary mixing in grasshoppers:switching induced by nutritional imbalances in foods. Entomologia Experimentalis et Applicata 61:247-254.

BROWN ES, DEWHURST CF. 1975. The genus *Spodoptera* (Lepidoptera: Noctuidae) in Africa and the Near East. Bulletin of Entomological Research, 65: 221-262.

CREECH RG. 1968. Carbohydrate synthesis in maize. Adv. Agron. 20: 275-322.

FANNY P, T RAVIKUMAR, MC MURALIRANGAN & KP SANJAYAN.1999. Influence of host on the duration of post-embryonic development and food utilization of *Oxya nitidula* (Walker) (Orthoptera: Acrididae). J. Ortho. Res., 8:119-124.

GABRIEL, BP. 2000. Insects and mites injurious to Philippine crops. UPLB College of Agriculture,Bulletin. 172p.

GRZYWACS D, MUSHOBOZI WL, PARNEL M, JOLLIFFE F, AND WILSON K. 2008. Evaluation of *Spodoptera exempta* nucleopolyhedrovirus (SpexNPV) for the field control of African armyworm (*Spodoptera exempta)* in Tanzania. Crop Protection 27: 17-24.

PRICE PW, CE BOUTON, P GROSS,BA MOPHERSON, JN THOMPSON & AE WEIS. 1980. Interaction among three trophical levels: Influence of plants on interaction between insect herbivores and natural enemies. Ann. Rev. Entomol. Syst. 11:41-65.

RIMANDO LC. 1954. A biological study of the black armyworm, *Laphygma exempta* Walker, Noctuidae, Lepidoptera. Unpublished Undergraduate Thesis, UP Los Baños. 37p.

ROSE DJW, DEWHURST CF, PAGE WW. 1996. The African armyworm handbook. Nairobi, Kenya: Desert Locust Control Organisation for Eastern Africa. 1st ed. Am. Press. 165p.

ROSE DJW, DEWHURST CF, PAGE WW. 2000. The African armyworm handbook. 2nd ed. Natural Resources Institute, Greenwich, UK, 304p. ISBN 0859545237.

SCRIBER JM & SLANSKY F. 1981. The nutritional ecology of immature insects. Ann. Rev. Entomol. 26: 183-211.

TABASHNIK BE, SLANSKY,JR. F. 1987. Nutritional ecology of foliage-chewing insects. In: F. SLANSKY,JR. AND JG RODRIGUEZ (eds). Nutritional ecology of insects, mites, spiders and related invertebrates. John Wiley and Sons, New York. pp. 71-103.