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Biological Studies of the Fall Armyworm (FAW) *Spodoptera Frugiperda* (J. E. Smith) (Lepidoptera-Noctuidae)

Anyang Longar Wol[1, 4], Andrew Modi Losia[2] and Sampson A-Koi Binyason[3]

1. Department of Crop Protection, School of Natural Resources and Environmental Studies, University of Juba, Republic of South Sudan

2. Department of Crop Protection, Ministry of Agriculture and Food Security, Juba, Republic of South Sudan

3. Department of Crop Protection, Western Equatoria University Technical College, Western equatorial State, Yambio, Republic of South Sudan

4. College of Agriculture, University of Bahr El-Ghazal, Wau, Republic of South Sudan

Abstract: The study for the Biology of fall army worm (FAW) *Spodoptera frugiperda* [1] was conducted at the Biology Laboratory of University of Juba, main campus, from 26th May through October, 2024, during summer months. University of Juba in South Sudan, lies between Lat. 4º 50´ 60N Long 3º 37´ 0 E and Alt. 550 meters above sea level (m.a.s.l.). The main objective was, twofold: i) to study the Biology of developmental stages of the FAW; eggs, larvae, pupae and adult through rearing ii) to determine the average duration of the stages and intervals within the stages while sub-specific objective was to detect critical weaker areas within the stages at which control measures could be designed to intervened appropriately to disrupt the lifecycle process of the insect, under the normal conditions of South Sudan. Results showed that, average incubation period for eggs to hatch completely was 3 days, ranged from 2 to 3 days at average temperature of ± 32 ºC, 87% R. H. under normal laboratory conditions. Colour of the eggs changed from creamy white, to brown and finally to black with the appearance of the young first instar larval head capsules as larvae emerged in mass numbers from egg shells. The average larval duration from first instar to end of 6th instar was 15 days, ranged from 15 to 18 days and the interval duration between instars was 2 days ranged from 2 to 3 days, under the laboratory average temperatures, ± 32 ºC, 87% R. H. Colour of the larvae remained pale yellow throughout but changed to greenish at the prepupal stages. Four black spots in form of a square, were observed at the 8th abdominal segments of the matured larvae. In addition, an inverted picture of letter “Y” was observed at the forehead of the larvae. The average pupal duration to adult was 11 days ranged from 9 to 13 days, under the normal laboratory average temperature of ± 33 ºC, 87% R. H. Colour of the pupae was predominantly, brownish to dark brown with no significant differences from those of other related species, as cited in the literature. Average duration of adult moth prior to its death was 7 days, ranged from 5 to 9 days, under the Laboratory average temperatures of ± 33 ºC. 87% R. H. While the average preoviposition period for moth was 4 days, ranged from 3 to 4 days. Colour of adult moths remained from grey to light grey for both male and female and different from other related species, *Spodoptera exigua* and *Spodoptera exempta,* cited in the literature. However, the males have white spot colour towards the tips of their forewings, not found in the female and with distinctive genital male character, different from the female.

Key words: Biology, egg, larvae, pupae, adult, FAW, *Spodoptera frugiperda.*

1. Introduction

The fall armyworm (FAW) *Spodoptera frugiperda* [1], which originated from the tropical and subtropical areas of the Americas, mostly in western hemisphere, has a long history of pest outbreaks, since its occurrence in 1797 [2]. The insect has recently entered sub-Saharan Africa through west and central Africa [3, 4] and has now, within this two years’ interval (2017 & 2018), covered over 60 nations in Africa, becoming a real threat to cereals, especially maize [5]. In South Sudan, FAW for the first time, was observed and reported by the national ministry of Agriculture and food security in areas of Magwi, Yei

Corresponding author: Sampson A-Koi Binyason, Ph. D., Research Prof., Entomology (IPM) Specialist.

and Juba, Equatoria region including Northern Bahar el- Gazal and parts of Jonglei State respectively [6]. There are a lot of speculations so far, regarding its presence in the African continent, how it travelled all these hundreds of miles from America to reach Africa? This is a period of about 220 years between its initial occurrences in 1797 and 2017, since it got established to the African soils. Other theorists say, it came by air probably cargo planes lifting relieve foods or materials from maize production areas in the United States, while others say by winds, through relieve seeds or planting materials. But here, one may even say human error could not be ruled out as one of the ways, with good or bad intentions!

From the current flow of literatures around the world, regarding its spread, FAW seems to effectively, demonstrate three very strong characteristics of its potential ability and capability: Firstly, its "fecundity," the egg production rate per female, averages about 1,500 to 2, 000 eggs with a duration of 2 to 3 days, during the warm summer season [7]; Secondly, its "Polyhagous" crop "preference propensity" to attack a wide range of crop species of over 350 plants [8, 9], causing enormous economic damage to key food crops like, maize, sorghum, rice, soybeans, vegetables and other commercial crops like cotton and sugar cane. Thus, rapidly expanding, poverty in sub-Saharan Africa. Thirdly, FAW is a strong flier, capable and can fly 500 km (300 miles) before oviposition with migratory and dispersal habit [7], able to migrate long distances [10].

As a new pest in the continent of Africa and especially in South Sudan, probably, this insect pest had travelled all this long distance without its natural enemies that, had kept it in check in the Americas. This situation, coupled with lack of quantitative control attempts in most of the invaded countries to halt its wide spread, exacerbated by presence of suitable environmental conditions, facilitated its rapid adaption in parts of Africa [11]. Therefore, there is a huge knowledge gap of control measures to be filled for FAW that, should urgently be acquired and appropriately inserted to disrupt the life cycle, halt its rampant dynamics and overwhelming activities on crop damages, in sub-Sharan Africa and beyond.

This narrative has prompted us to decide and enthusiastically, study the biology of developmental stages of the FAW, *Spodoptera frugiperda (*J. E. Smith) under the local laboratory conditions. It was deliberately intended to delve and detect or identify some weaker and vulnerable areas within its life cycle process through which interventions of control measures could be effectively applied to disorganize the entire development process at the early stages. We are targeting the period between the last days of egg-hatching through the 1st, 2nd and end of the 3rd larval instar, as the critical vulnerable and delicate point at which control can be effective. At this stage, we imagine the young larvae emerge in masses or swarms in the natural field environment, idly loitering in the surroundings with mouth parts weak to bite, looking for food and shelter, in order to survive. In so doing, the entire larval masses are exposed to physical hardships like, presence of natural enemies (predators, parasites), hot sun, rains, strong winds or access to chemical contacts enduring through to survive. This is where we think, it is then, possible to engage an integrated pest management control intervention for its effective control and management.

2. Materials and Methods

2.1 The Study Area

The Study of the Biology of fall armyworm *Spodopetra frugiperda* (J. E. Smith) was conducted at the main Biology Laboratory in the main campus of University of Juba, in South Sudan, (Lat. 4º 50´ 60 N Long. 3º 37´ 0 E and Alt. 550 meters above sea level (m.a.s.l.). The primary objective was twofold: i) to study the Life cycle of the FAW, *Spodoptera frugiperda* (J. E. Smith) under South Sudan eco-zone conditions, through the rearing of developmental stages of the insect, (egg, larva, pupa and adult),

determine average duration of each stage and intervals, and ii) the sub-objective was to detect critical and vulnerable weaker areas discovered within the life-cycle process in which control measures deliberately intervened to disrupt the entire process. The target crop was maize (*Zea mays*), which is the major staple and economic food crop especially, in the Greater Equatoria Region, of South Sudan.

2.2 Materials Used for the Study

The materials used for the study included; 70 small plastic rearing cups of (2 x 2 x 5) cm, white pieces of cloth as cover, a pair of scissors, rubber bands, a tray, fresh maize leaves, smart phone, a wooden cage, folded white papers and a branch of plant leaves for egg deposition, cotton plugs, sugar solution, threads, nails, fine brush for separation of the larvae, wire mess, a thermometer, petri dishes, a small boat and small plastic basket for insect collection.

Fig. 1 Rearing plastic cups.

Fig. 2 Wooden cage for rearing adult moth of FAW.

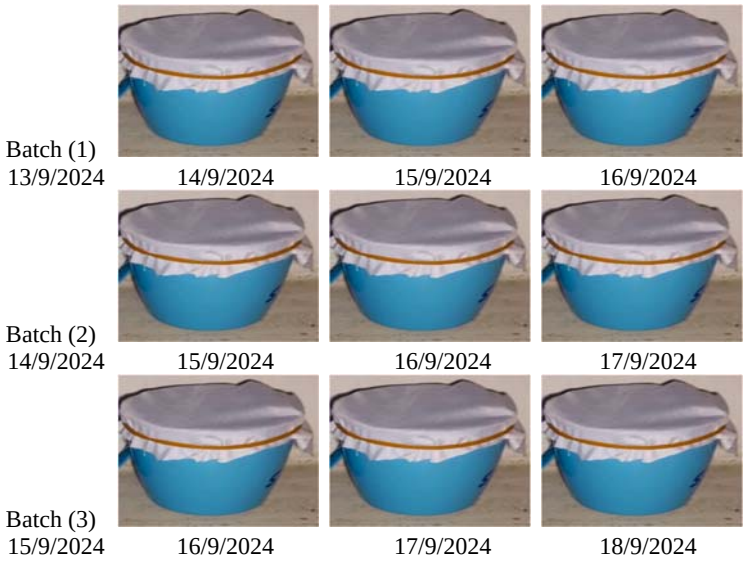

Fig. 3 Rearing of egg-batches of FAW.

2.3 Establishing the Insect Culture

Larval stages of fall armyworm, *Spodoptera frugiperda* belonging to various age groups and body sizes, were initially collected from the maize infested fields at Juba-Na- Bari Island, across the White Nile River. Juba Na-Bari Island, is located 500 meters north of Juba City. The White Nile River was crossed using a small boat. The larvae were randomly collected, individually, or sometimes together with parts of the damaged maize plants and put into a basket. They were brought to the Laboratory, poured on a tray, sorted and segregated into age instars or body sizes of small groups and put into each rearing cup (2 x 2 x 5) cm. for raising and establishing the FAW culture.

2.3.1 Methods for Rearing the Larvae

The small collected various groups of larvae were put in each rearing plastic cup described above and were continuously reduced into few in numbers reaching to 4 or 3 per each cup to avoid cannibalism. Each rearing cup was provided with soft fresh maize leaves for the larvae to feed on as they grow. Each cup was, covered with a white piece of cloth and tightened with rubber bands to prevent the larvae from coming out or interferences of predators. The leaves were replaced every 2-3 days as they become dry and the larvae were maintained until they developed into the pupal stages and finally to adult moths. The duration of each larva or larval groups was recorded in days from the 1st day they were collected until they reached the 6th instar stage when the larvae changed completely to pupae and the average duration date of development from the date of collection to the 6th instar was determined. Durations in rearing the pupae and adult stages were determined in a similar manner.

3. Results

3.1 The Egg Incubation Period

The first egg batch that was taken for incubation from the wooden cage on the first day (13/9/2024) was monitored for 2 to 3 successive days, until all eggs hatched on the 4th day, (16/9/2024). This was also done for batches 2 & 3, respectively. On the first day, the egg colour was creamy with slightly cottony white cover. Within 2-3 days, the eggs began to change color, from the white creamy to brown and from brown to black on the 3rd and 4th day. All eggs almost hatched within this period and masses of young larvae emerged in big numbers spreading out looking for food and shelter from the 4th day onwards. However, the larvae remained trapped by the green

fresh maize leaves which were provided in advance into the cups as the eggs began to change black in colour before they (larvae) emerged. The incubation period for the 2nd and 3rd groups of egg-batches which were taken and monitored on 14/9 and on 15/9/2024 respectively, showed similar results during the observation period, though with variations on the duration periods. The average duration for the incubation period of eggs of FAW *Spodoptera frugiperda* which ranged from 2-3 days was therefore 3 days, under the normal Laboratory temperature of ±32 ºC. 87% R. H. Results are shown in Fig. 4 (a, b, c & d), Fig. 5 (a, b, c & d), Fig. 6. (a, b & c) and Table 1.

(a) 13/9 (b) 14/9 (c) 15/9 (d) 16/9/2024

Fig. 4 Showing first egg batch.

(a) 14/9 (b) 15/9 (c) 16/9 (d) 17/9/2024

Fig. 5 Showing second egg batch.

(a) 15/9 (b) 16/9 (c) 17/9/2024

Fig. 6 Showing third egg batch.

Table 1 Egg incubation period from 1st batch, 2nd batch and 3rd batch.

Egg batch	Date	Duration of incubation	Average number of days
1st egg batch	13/9/2024	2	
2nd egg batch	14/9/2024	3	3 days
3rd egg batch	15/9/2024	3	
Average temp.		2 to 3 days	± 32 ºC, 87% R. H.

1st 2nd 3rd 4th 5th 6th

Fig. 7 Showing larval development stages in the laboratory.

Table 2 Shows larval development period.

Larval stage	Date	Duration incubation days	Average number days
1st instar	15\9 \2024	2	
2nd instar	17\9\2024	3	
3rd instar	20\9\2024	2	2 days
4th instar	22\9\2024	3	
5th instar	25\9\2024	2	
6th instar	27\9\2024	3	
Average temp.		15 to 18 days	± 32 ºC, 87% R. H.

3.2 The Larval Development Period

The first larval stages known as first instars that emerged from the first egg batch on 15/9/2024 were carefully transferred in small groups into the rearing plastic cups (2 x 2 x 5) cm and were reared as described in (2.3.1.), beginning from the first instar date, (15/9/2024) until they reached the 6th larval instar stage. As the larvae grew in sizes and numbers, they were continuously reduced in number and separated into more rearing cups in small groups and later in threes or finally, two larvae in each cup, to avoid cannibalism. The average intervals between instars and the average duration in number of days from 1st instar to end of 6th instar for each larval group were determined. The average number of days between two larval instars ranged from 2 to 3 days and the total number of larval development days from 1st instar to end of 6th instar ranged from 15 to 18 days, under the normal Laboratory Temperature of ± 32 ºC, 87% R. H. The results are shown in Fig. 7 and Table 2.

3.3 The Pupal Development Period

The pupae that developed from the same larval batches as described in (3.2) belonging to the respective dates of (1/10/2024, 3/10/2024 and 5/10/2024) of the group batches respectively, were similarly, transferred to the rearing plastic cups (2 x 2 x 5) cm, resting on filter papers. They were maintained and monitored in these cups until emergence of the adult moths. The pupae are mahogany brown in colour and difficult to differentiate the male from female at this stage or

distinguish them from pupae of other species, like *Spodoptera exigua* or *Spodoptera exempta.* The average duration period for the pupae was similarly calculated from the sum of 3 pupal batches as described previously. The average duration period for the pupal group batches, was therefore, 11 days, ranging from 9 to 13 days under the normal Laboratory Temperature of ± 33 ºC. 87% R. H. Results are in Fig. 8 and Table 3.

3.4 The Adult Moth Development Period

The adult moths emerging from the batch groups of 10/10, 14/10 and 17/10/2024 respective dates were released into the wooden cages for monitoring and observation on egg laying. The pre-oviposition period (first day of adult moth emergence to the first day adult moth starts laying eggs) was determined. The life span (first day of adult moth emergence to last day adult moth dies) was also calculated. The average pre-oviposition period for *Spodoptera frugiperda* under the normal Laboratory Temperature of ± 33 ºC 87% R. H., was 4 days, while the life span under the same Temperature was 7 days ranging from 5 to 9 days. The results are shown on Fig. 9 and Table 4.

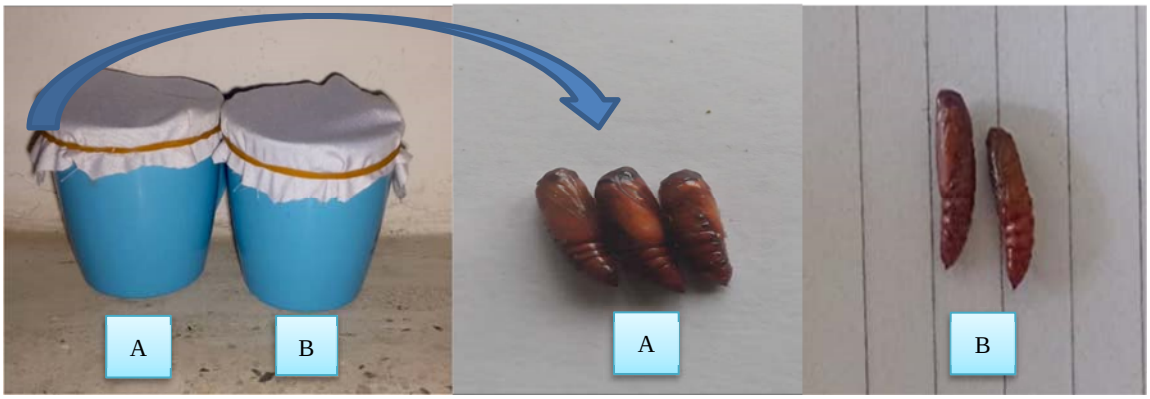

Fig. 8 Pupae development period.

Table 3 Pupal development period.

Pupal stage	Date	Duration to adult stage	Average number of days
1st batch	1\10\2024	9	
2nd batch	3\10\2024	11	11 days
3rd batch	5\10\2024	13	
Average temp.		9 to 13 days	± 33 ºC, 87% R. H.

Fig. 9 Showing adult moth (FAW) *Spodoptera frugiperda* Lab. U. o. Juba 2024.

Table 4 Adult moth development stage and its life span.

Adult stage	Date of emergence	Life span duration	Average life span
1st batch	10\10\2024	8	
2nd batch	14\10\2024	5	7 days
3rd batch	17\10\2024	9	
Average temp. & R. H.			±33 ºC, 87% R. H.

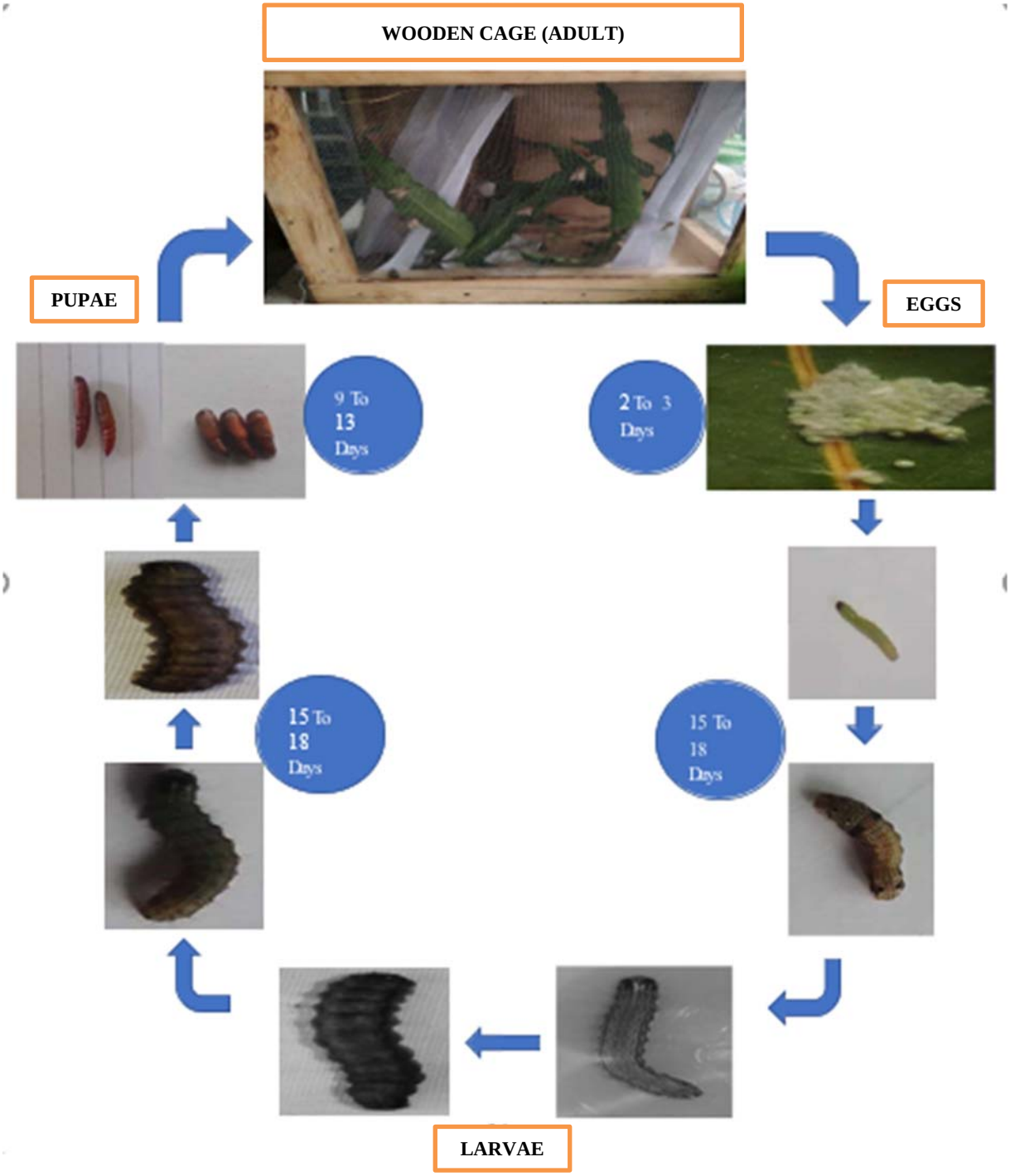

Fig. 10 The life cycle of fall armyworm (U. O. J.) 2024.

4. Discussion

4.1 The Egg Incubation Period

The average egg incubation period for *Spodoptera frugiperda* which ranged from 2-3 days, was 3 days, under normal laboratory conditions at average temperature of ± 32 ºC, 87% R. H. in South Sudan. This is according to results obtained in the laboratory at University of Juba in September, 2024. The colour of the eggs kept changing rapidly daily, from white creamy to brown and finally to black from the 2nd and 3rd day, showing the black head capsules of the developing larvae before the complete hatching of the egg messes. These results concur with those of Prasanna et al. [7] who stated that, duration of the egg stage was only 2 to 3 days during the warm summer months. Similar results were obtained for *S. exigua* where the eggs hatched within 2 to 3 days during warm weather, but the incubation period was extended to about 4 days when it was cool [12].

4.2 The Larval Development Period

The average development period for the larvae, reared in the Laboratory from 1st instar to the 6th instar which ranged from 15 to 18 days, was 15 days and the average duration between instars which ranged from 2 to 3 days, was 2 days, under average temperatures of ± 32 ºC - 33 ºC, 87% R. H. (Table 2). The whole life cycle of the insect ranged from 31 to 43 days which was about 4 to 6 weeks. These results concur with those of Padhee and Prasanna [13] who reported that, the life cycle of the insect may take from 30 to 45 days depending on the weather conditions. The larvae in high densities was cannibalistic and therefore, was maintained in small numbers reducing from 3 to 2 per cup (2 x 2 x 5) cm, to avoid cannibalism. The life cycle under similar conditions in the laboratory, was completed in 3 stages; the egg, larvae (6 instars), pupae and finally the adult stage. This life cycle results concur with those of FAO [6], but different from that of *Spodoptera exigua* ending only with the 5th instar and takes about 3 weeks. The larvae of *Spodoptera frugiperda* at their last development stages (5th to 6th instars, bear four dark spots in form of a “square” at the 8th abdominal segment and an image of letter “Y” inverted at its forehead. These similar features have been reported earlier by Ashley et al. [14] and FAO [5]. The larval instar is the most destructive stage. The young instar larvae, still with weak undeveloped mandibles, start feeding around the surroundings after emergence. As the larvae grew up and mandibles fully developed, they started to attack the leaf tissues of the provided fresh maize leaves, making holes from the 3rd and 4th instar. The densities of larvae in small groups were reduced from few to even 3 to 2 per cup to avoid the cannibalistic behavior. Abraham et al. [15] reported similar behavior of the grown-up larvae on maize crop during his field studies.

4.3 The Pupal Development Period

The average development period for the pupae of *S. frugiperda* under normal laboratory conditions which ranged from 9 to 13 days at average Temperature ± 33 ºC, 87% R. H., was 11 days, although there were variations of 2 to 3 days among the pupal’ batches (Table 3). These results were more by 4 days compared to those of *S. exigua*, which may probably be due to differences in weather conditions as they were reared at different ecological zones. The pupae were all red to dark brown in colour and shiny with no much differences with those described by CABI [16] and Sharanabasappa et al. [17]. These results may also concur with those of Vickery [18] who stipulated that pupal period may extend from 7 to 37 days depending on the soil mean temperature from 59-84 ºF though the laboratory temperature at University of Juba was 33 ºC, 87% R. H. and the pupae not in soil environment.

4.4 The Adult Moth Development Period

The average development period for the adult moth

of *Spodoptera frugiperda*, from the first day of emergence to the last day of its death which ranged from 5 to 9 days among the adult moth batches, was 7 days. This was under the normal Laboratory conditions of average temperature ± 33 ºC, 87% R. H., with variations among the adult moth batches (Table 4). There were clear morphological differences between features of the male and female adult moths in references to colour and genital structures. The FAW *Spodoptera frugiperda* under the laboratory conditions in University of Juba completed its life cycle in 3 stages; Egg, Larval (six instar larval stage) Pupal and Adult Stage, between 31 to 43 days. The results concur with those of FAO [5].

5. General Discussion

When FAW *Spodoptera frugiperdan* suddenly, emerged through west and central Africa [3], it spread very fast covering many sub-Saharan countries [19] and threatening food security [20]. Because of its ability to produce many eggs, propensity to attack many crops (polyphagous) and tremendous energy to migrate over long distances (500 km or 300 ml Rose et al. [10]), the insect quickly got adapted into the conducive sub-Saharan climate, without challenges, within this short period.

Several reports ensued by governments in the countries invaded by the insect pest, but most of them merely trashed campaign propaganda for soliciting funds. There were no initiatives to conduct quantitative biological studies for better understanding of the lifestyle of the insect to halt the spread dynamics. Most of the invaded countries concentrated on alarms, mobilization of communities' awareness about the presences of the insect, mode of crop damages and nothing regarding its control management.

As an alien pest in Africa, and with the experiences gained from the activities of the indigenous species; *Spodoptera exigua* and *Spodoptera exempta* in field environments, the major objective for the study was therefore twofold: i) to study the life cycle and determine the average development period for each of its stages; (egg, larva, pupa and adult) and ii) the sub-objective was to detect weaker or vulnerable areas within its life cycle, in which control measures could intervene under local environmental conditions of, temperature and relative humidity. This was conducted at the University of Juba in South Sudan, being a different ecological zone, in sub-Saharan Africa. The prompting and encouragement to study the biology of FAW *Spodoptera frugiperda* was to concentrate focus, at delicate areas within the developmental stages perceived appropriate for intervention with control measures that would yield fruitful results in saving economic crop damage. The results obtained from the study hopefully will place us into a better position on how to effectively control FAW at a specific development stage. The study specifically, targeted the period between; "egg-hatch through 1st, 2nd and 3rd larval instar". This period was considered, critical and a vulnerable stage. The larvae had just emerged and desperately searching for food and shelter, mouth parts (mandibles) are still weak to bite a plant tissue and await fully development, larvae under field conditions are exposed into predation by natural enemies, physical harsh natural conditions like, strong winds, hot sun, cold temperatures, rains and access into contacts with toxic materials like, insecticides. Therefore, with all this myriad, the insect has narrow chances of survival. The results obtained from the study indicate or suggest that, application of a well- designed IPM package as a control intervention within 7 to 10 days after the emergence of its first instar larval stage, is sufficient and effective to disrupt the life cycle of FAW *Spodoptera frugiperda*. Simultaneously, in pursuance of our objective, we give a pledge to the student to proceed with an IPM Ph. D., research programme to test the effect of some selected Bio and Synthetic insecticides against the insect at this critical stage in the laboratory. The experiment will be

replicated under field environment using the same selected insecticides under field natural conditions against the insect within the 7 to 10 days after its emergence. As we explore for more effective control measures against the FAW, the second alternatives is, to determine and use economic threshold levels, advocating to stop the unnecessary application of insecticides which goes well with the IPM principles. This will guarantee safety, prevent environmental pollution and protect human health. We therefore appeal to Donor Organizations like, UN FAO, JICA, UK and USAID for funding this important research proposal.

6. Conclusion

An effective and successful control and management of the FAW *Spodoptera frugiperda* or any of its related species; *Spodoptera exigua* and *Spodoptera exempta*, can be achieved through studying their biology. This gives more understanding of the developmental stages; egg, larva, pupa and finally the adult stage under laboratory conditions and determine the average duration of each stage in number of days. The study will also provide opportunities to detect vulnerable and weak areas in which control interventions can be appropriately, inserted to disrupt the entire life cycle. The results of this study have indicated that, the period between the 1st, 2nd and end of 3rd larval instar which is a period from, 7 to 10 days, as the most critical and vulnerable period for the insect to survive. This is where we strongly believe control measures should be effectively, implemented

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