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RESEARCH PAPER

Studies on life cycle of fall armyworm (*Spodoptera fugiperda*, J. E. Smith) reared on *rabi* sorghum leaves

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Abstract: Studies on life cycle of fall armyworm (*Spodoptera frugiperda* J. E. Smith) reared on fresh sorghum leaves was conducted at the Department of Agricultural Entomology, College of Agriculture, Dharwad during the *rabi* season of 2019. The number of egg per egg mass, duration of egg mass, larvae, pupae, adult life, adult longevity, pre-oviposition, oviposition and post- oviposition, fecundity and number of egg masses/female were recorded. The total egg, larval and pupal period ranged between 4 to 4.33, 15 to 17 and 6.33 to 9 days, respectively. Thus the total life cycle had a range of 30 to 35 days.

Keywords: Fall armyworm, Life cycle, Oviposition, Sorghum

Introduction

Sorghum (*Sorghum bicolor,* L. Moench.) is a worldwide economic cereal crop cultivated in throughout the entire world. It is regarded to be one of the world's important economic cereal crops that belongs to *Poaceae* family. According to Jotwani *et al*. (1980) and Sharma (1993),sorghum is infested by nearly 150 insect species complex of which the shoot fly is a major one followed by stem borers. Recently introduced fall armyworm, *Spodoptera frugiperda* (J .E. Smith) is of great worry because of its high defoliating capacity and polyphagous nature. The fall armyworm (*Spodoptera frugiperda)* is a lepidopteran pest that has been recognized as an injurious pest to an extensive range of crops, especially the Graminae. It causes significant damage to cultivated grasses of commercial importance such as maize, sorghum, rice, sugarcane, including other important legumes and cotton (Nagoshi *et al*., 2018). In India, the first occurrence of this pest on sorghum and bajra was noticed during October 2018 at the fields of Agricultural Research Station, Ananthapuram district, Andhra Pradesh, India. The damage on sorghum fields was up to the extent of 70 per cent, while in bajra it was up to 30 per cent (Venkateswarlu *et al*., 2018). In sorghum, FAW infestations in the whorl reduced grain yields of susceptible lines by 55-80 per cent (Andrews, 1988).

With this background present studies on the lifecycle of fall army worm on rabi sorghum genotype SPV 2217 was carried out to determine the duration of each stage (*viz.*, egg, larva, pupa), adult longevity, fecundity, pre-oviposition, oviposition, and post- oviposition period which forms the basic prerequisite for further studies on the pest in the particular geographical location.

Material and methods

Laboratory studies on the biology (lifecycle) of fall armyworm were carried out at the Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad during *rabi* season of 2019, by rearing it on sorghum variety SPV 2217. Pure culture of fall armyworm was initiated by collecting egg masses and immature stages of the pest from the sorghum fields. These eggs were maintained in the laboratory at 25 ± 1 °C, humidity 70 ± 10 per cent and 14 h photophase until hatching. While the larvae were reared on fresh sorghum leaves which were changed daily till pupation. A pair of newly emerged adults was released into a wooden cage of 36x36x36 cm^3 dimension for egg laying. 10 per cent honey solution was provided on cotton in 30 ml paper cups which served as food for adults. Fresh tender sorghum leaves were also kept in the cage for egg laying. The cut end of the leaf whorl was covered with wet cotton wad for maintaining leaf freshness. The egg masses obtained from this were used for further study of biology.

For incubation studies, ten freshly laid egg masses along with the leaf were kept in rearing boxes and provided with wet blotting paper to prevent desiccation of eggs. Once the eggs turned to black, fresh sorghum leaves were provided which served as food for newly hatched larvae. Observations were recorded on the number of eggs per mass and incubation period for individual egg mass and mean of value of ten masses was worked out.

For studying the larval period, three replications consisting of ten neonate larvae were maintained at 25±1 °C, humidity 70±10% and 12 h photoperiod in three rearing boxes. The top portion of the boxes were covered with muslin cloth to facilitate aeration. Later the larvae were reared individually from late 2^{nd} instar till pupation to avoid cannibalism. Fresh sorghum leaves were provided as food for the larvae every morning. Once the larvae entered last instar, soil bed was provided at the bottom of the box for pupation. Observations were recorded daily to determine the number of larval instars, duration of each larval instar, total larval period, pre-pupa and pupal period and total life cycle. Further, the morphological characters such as colour, shape, habits of larva were recorded.

The biological characters of adults such as pre-oviposition and oviposition periods, fecundity, sex-ratio and adult longevity were also recorded. For this, five pairs of newly emerged male and female moths were enclosed in the rearing cage at the rate of 1 pair per cage. 10 per cent honey solution was placed as food for adults. Fresh sorghum leaves with wet cotton wad at the cut end was provided in each cage for egg laying. The egg masses laid everyday were accounted till the death of female moth. Number of eggs per mass was counted. Adult longevity of male and female moths were also recorded.

Results and discussion

Egg

The adult female moth deposited eggs in masses mostly on the adaxial surface of the fresh leaf. The lower leaf surface was least preferred. But under high pest density, female moths laid eggs on the lower leaf surface also. Under field conditions, female moths deposited eggs on the upper side of leaves. This is in accordance to previous reports of Kumela *et al*. (2019) that fall armyworm eggs are laid on the adaxial side of leaves as the caterpillars emerging out of the egg masses spin onto other plants and migrate to the leaf whorl where they burrow and feed by remaining within the whorl of plants into the whorl. after hatching the newly emerged larvae fee. However, some earlier researchers reported that eggs are laid underneath the leaf surface, near the base of the plant and sometimes, when populations are high eggs are deposited on the adaxial side of the leaf (Anon., 2019). Further more, under field conditions, the FAW lays eggs both dorsal and ventral surface of leaves and as well as the inner leaf whorl is in accordance to Sharanabasappa *et al*. (2018).

Freshly laid fall armyworm eggs were creamish-white in colour, dome-shaped with flattened base. Some eggs were deposited two layers while some only had one layer attached to foliage. The female deposits a layer grey tuft hairs or scales over the egg masses which gives them a greyish mouldy appearance. After two days of incubation period, a light brownish colour appeared on the adaxial surface of the eggs indicating their readiness to hatch. The unfertilized eggs didn't have colour change while they gradually shrivelled. Incubation period of egg masses varied from 4 to 4.33 days with a mean of 4.10 days (Table 1). The observations made on egg during the present investigation revealed that the egg was dome-shaped with a flattened base and initially creamish-white in colour with scales from the adult female covering them thus giving a mouldy appearance and later turned brown before hatching occurred. The egg period occupied around 4 to 4.33 days. Most of the eggs hatched in early morning hours while few hatched late in the evening. This is in agreement with reports conducted by Capinera (2002), Shylesha *et al*. (2018) and Babu *et al.* (2019) who recorded a more or less similar egg shape for the fall armyworm with around 4 days egg period under optimal conditions.

Larvae

During larval period the caterpillar of fall armyworm underwent five moults with six instars when reared on fresh sorghum leaves. In the present investigation, six larval instars were noticed on sorghum occupying an average larval period of 15.5 days ranging from 15 to17 days during the months of November- December under laboratory conditions which is in close agreement with reports of Praveen and Mallapur (2019) who noted that the larval duration was shortest for the larva which fed on sorghum (18.51 days). Present study also matches studies of Anon. (2016) and Kalleshwaraswamy *et al*. (2018) stating that the insect undergoes through six instars over a period of 14 to 19 days.

Table 1. Biology of fall armyworm reared on *rabi* sorghum during Nov-Dec 2019

Stages	Duration (Days)	
	Mean ± SD	Range
Incubation period	4.1 ± 0.16	4-4.33
Total larval Period	17.5 ± 1.10	15-17
I Instar		2.16 ± 0.24
2-2.66		
II Instar	2.16 ± 0.22	2-2.66
III Instar	3.33 ± 0.27	3-3.66
IV Instar	3.33 ± 0.16	3-3.66
V Instar	2.4 ± 0.34	2-3
VI Instar		2.16 ± 0.18
2-2.66		
Pupal period	7.5 ± 0.89	6.33-9
Total life cycle (egg to adult)		
Female	32.5 ± 3.54	30-35
Total life cycle (egg to adult) Male	31 ± 2.12	30-32
Female adult Longevity	7.46 ± 0.24	7.33- 8
Male Adult longevity	7 ± 0.36	6.33-8
Pre-oviposition period	7.4 ± 0.27	7-8
Oviposition period	3.26 ± 0.20	3-3.66
Post oviposition period	1.43 ± 0.27	1-2
Fecundity per female (No.)	992 ± 13.85	792-1052
Number of egg mass per female	0.23 ± 0.12	2-5
Number of eggs per egg mass	165.0 ± 4.95	112- 218
Egg hatchability (%)	96.5 ± 2.12	95-98

Newly hatched neonate larvae were soft, tiny, active, slender and cylindrical in shape with a black head. The larval skin was smooth and greenish in colour. The larval duration of the first instar ranged from 2 to 2.66 days with a mean of 2.16 days (Table 1). When neonate larvae got exposed to light, it moved away to the dark concentrated part of the host plant (food) where it fed on the host plant by scraping the leaves and giving the host plant a papery appearance. This matches the reports conducted by Capinera (2002) who mentioned that neonate larvae are very tiny and greenish in colour. The larvae increased in size with change of body colour to orangish and appearance of lateral white lines. The head also turned to orangish. Duration of the second instar ranged between 2 to 2.66 days with a mean of 2.16 days (Table 1).

The larvae further increased in volume and size as it reached third instar. There was no remarkable change in the colour of skin, however the lateral white lines became more prominent. The head of the larvae was light brown in colour. The larvae started feeding on the leaves by chewing, as compared to the

earlier two instars which fed on the host by scraping the host leaves. An inverted 'Y' shape line started appearing on the head capsule with clearly visible 'four black dots' on the 8th abdominal segment. The duration of the third instar varied from 3 to 3.66 days with an average of 3.33days (Table 1). Here, the larvae increased in size. The dorsal side was green in colour with exception of brownish dorsal side bearing spines appearing dorsally. However, the body colour was not constant, it ranged from light green to brown of the larval head varied from light to dark brown in colour, and the inverted 'Y' became more prominent. The period of the fourth instar ranged from 3 to 3.66 days with a mean of 3.33 days (Table 1). These findings are in line with reports conducted by Shylesha *et al.* (2018) who noticed that the inverted 'Y' on the head capsule became visible.

The larvae had a brownish body with lateral white sub dorsal lines and elevated spots bearing spines appearing dorsally. Four prominent black spots which appeared as a square were more prominent on the 8th abdominal segment. The colour of the head was dark brown with a prominent inverted 'Y' shape mark. The duration of the instar stretched from 2 to 3 days with a mean of 2.4 days (Table 1). The larval colour was brownish and it was fleshy and had increased in size bearing lateral white sub dorsal lines and elevated spots bearing spines appearing dorsally. The colour of the head was dark brown with prominent inverted 'Y' shape and four dark spots shaped in a rectangular manner were observed on the 8th abdominal segment. Following the sixth instar, the larvae became inactive, sluggish, shape contracted and the skin became rough. It stopped feeding by the end of the sixth instar. The duration of the instar varied from 2 to 2.66 days with a mean of 2.16 days (Table 1). This matches findings of Kumela *et al*. (2018).

Pupa

The extent of pupal period occupied 6.33 till 9 days with a mean of 7.5 days. Pupation took place in the soil that has been collected from the field and placed inside the petri-plate to mimic field conditions. This is in also in accordance to reports by Anon. (2016) who reported that pupation took place at a depth of 2 to 8 cm or 1 to 3 inch. These findings are in close agreement with Capinera (2002). The colour of the pupa was coppery in colour, obtect and exhibited sharp cephalic part with a broad anterior and tapering posteriorly to a pointed tip and this matches the findings of Sisodiya *et al*. (2018) and Anon. (2018) confirmed that the pupa was reddish brown in colour with cremaster. The pupal period was 6.33 to 9 days. Praveen and Mallapur (2019) observed that the pupal period of FAW surviving only on recorded the lowest pupal period of 8 days, which is similar to findings of this present investigation. Also Deole and Paul (2018) and Capinera (2002) recorded similar findings by stating that the insect pupates in the soil for 8-9 days.

Sex differentiation

Sexes could be distinguished at pupal stage by carefully observing under the microscope based on the distance between the genital opening and anal slot. The posterior portion of the male was narrow and the female's was broad. In both sexes, the anal slit was on the 10th segment of the abdominal segment. In male genital opening was located on the 9th abdominal segment whereas in female it was located on the 8th segment. The distance was more on female and less on male. This is in agreement to the findings of Kalleshwaraswamy *et. al*. (2018).

Total life cycle

The total life cycle of the male moth ranged between 30 to 32 days with an average of 31 days, while that of female adult moth life cycle ranged between 30 to 35 days with 32.5 days as the average. The outcomes are in close conformity with Kalleshwaraswamy *et al*. (2018) who reported that the total life cycle of the male and female ranged between 32-43 and 34-46 days, respectively. However, Capinera (2002) recorded the lifecycle duration in summer occupying 30 days, spring with 60 days and 80-90 days in winter. This may be due to varied ecological and climatic conditions of that particular locality.

Adult longevity

The longevity of the adult male moths in this study ranged between 6.33 and 8 days with a mean of 7 days while longevity of adult female ranged between 7.33 and 8 days having a mean of 7.46 days. This matches with reports conducted by Capinera (2002) who stated that the length of adult FAW life is likely to be around 10 days. The variation may be due to prevailing climatic conditions and ecological factors like temperature, humidity and food.

Pre-oviposion period

Emergence of adult moth was observed during night hours and rarely during day time. Soon after emergence, a creamish pink-brown thick fluid was observed oozing out of the anus of the moth. The moth was and inactive for some time soon after emergence. The thorax and abdomen were full of scales, abdomen was conical, broader at the base and gradually tapering towards the apex. The forewing of the male adult was shaded with greyish brown colour, bearing triangular white patch around the apical region and circular spot at the centre of the wing. The forewing of the female was uniform greyish brown to a fine mottling of grey and brown in colour. Moreover the hind wing was silver-white with a narrow dark border in both male and female. The female pre-oviposition stage occupied a period of 7-8 days with a mean of 7.40 days (Table 1).

Oviposition period

The oviposition stage of the female moth ranged between 3 to 3.66 days with a mean of 3.26 days (Table 1). The adult female moth laid eggs in masses on the upper surface of the fresh host leaf (sorghum) which was provided as an oviposition substrate inside the adult rearing cage. Egg were laid inside the leaf whorl in a circular manner, overlapping in two layers without any interspace. This matches reports of Capinera (2002) and Nagoshi *et al*. (2018) who stated that eggs were laid on the upper surface mostly with one layer of egg mass, but sometimes the egg overlapped in two layers. The eggs were laid during

night hours, but occasionally, they were observed laying eggs during early morning hours.

Post oviposition period.

In this period, the female stopped laying eggs and became inactive, although minimum movements were observed. It hid inside the leaf whorl of the host plant. The duration of the post oviposition period ranged between 1 to 2 days with a mean of 1.43 days (Table 1).

Fecundity/female

The average eggs laid per female was 992 with a range of 792 to 1052 which is similar to the works of Anon. (2016) which stated that the number eggs each female laid in its entire adult life ranged from 1000 to over 2000 eggs. The quantity of eggs per egg mass was between 112 to 218 eggs with a mean of 165 eggs per egg mass and this matches the reports from Capinera (2002) who mentioned that the quantity of eggs per egg mass was between 100 to 200.

Number of eggs/egg mass

The number of eggs per egg mass varied from 112 to 218 with an average of 165 eggs/mass. The number of egg masses per female varied from 2 to 5 masses with an average of 0.23 (Table 1) egg masses per female. This matches reports of Capinera (2002), Anonymous (2016) and Sharanabasappa *et al*. (2018) who stated that the eggs in egg masses may vary between 100 and 200. Within an egg mass, not all eggs hatched. The per cent hatchability ranged between 95 to 98 per cent with an average of 96.5 per cent (Table 1).

The results of the present investigation revealed that, SPV 2217, a popular ruling variety of *rabi* sorghum in Dharwad region did not have any influence on the lifecycle of fall army worm under laboratory conditions. And thus further studies on management of the pest under field situation at appropriate stages could be formulated based on results of present investigation.

Conclusion

Studies on life cycle of fall armyworm (*Spodoptera frugiperda* J. E. Smith) reared on the popular *rabi* sorghum variety SPV 2217, revealed that the duration of different life stages of the pest such as egg, larvae and pupal period ranged between 4 to 4.33, 15 to 17 and 6.33 to 9 days, respectively with a total life cycle of 30 to 35 days under laboratory conditions.

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