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BIOLOGY AND NUTRITIONAL INDICES OF THE FALL ARMY WORM *SPODOPTERA FRUGIPERDA* (J E SMITH) ON MAIZE

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ABSTRACT

Lifecycle, progressive growth of larval head capsule, and nutritional indices of *Spodoptera frugiperda* (J E Smith) on maize (Co-H6) were studied at the Department of Agricultural Entomology, TNAU, Coimbatore during 2018-19. Incubation, total larval, and pupal periods were observed as 2-3, 13-20, and 7-11 days, respectively. The total lifecycle of male and female was 33-46 and 35-47, respectively. The head width was observed to be 0.34, 0.60, 0.89, 1.32, 1.86, and 2.36 mm from the first to the sixth instars, respectively. Linear regression analysis showed a significant relationship between larval instars and head capsule width (R^2=0.0979); and geometric progression ratio was observed as 1.48. Nutritional indices were also studied for the third and fifth instar on the maize plants. Consumption index (CI) and approximate digestibility (AD) increased with larval age, while efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) were inversely related to age. These values for the third and fifth instar were- CI= 2.30 and 2.31; AD=35.7 and 40.29; ECI=18.33 and 12.21; ECD=51.33 and 30.3, respectively.

Key words: *Spodoptera frugiperda*, maize, fecundity, egg, larval, pupal periods, lifecycle, stages, larval instars, head capsule width, Dyar's law, nutritional indices.

The fall army worm (FAW) *Spodoptera frugiperda* (J E Smith) is an invasive polyphagous pest in India since 2018 (Shylesha et al., 2018; Mallapur et al., 2018). It is emerging as the most destructive pest of maize and has spread rapidly to all maize growing regions. Yield reductions in maize due to its feeding had been reported to be as high as 34% (Cruz, 1999; Williams and Davis,1990). Besides corn, it feeds on the leaves and stems of >350 plant species, including rice, sorghum, sugarcane, and wheat. Knowledge on its biology is important for identifying lifestages and for planning IPM strategies. This study analyses its biology at different crop growth stages on maize. The progressive growth of larval head capsule, and the nutritional indices are also brought out.

MATERIALS AND METHODS

The field collected larvae of FAW from maize fields of Tamil Nadu Agricultural University, Coimbatore were reared in the laboratory on 15-20 days old maize seedlings CoH-6 (26± 2^0C, 75- 80% RH) during July 2018. Larvae were fed with fresh leaves daily till pupation. On pupation, the pupae were transferred on to sand in plastic petridishes (90x 40 mm). The pupae were sexed based on the genital pore on the abdominal segments. In the ovipositional cage a pair of pupae (male and female each) were placed for emergence. On emergence of adults, potted maize plants of 15-20 days old were placed inside the cage (30x 30x 45cm) as ovipositional substrate. Adults were fed with 10% honey solution dipped in cotton swabs and placed in glass vials. The eggs laid were collected and used for studying the biology. On hatching, the larvae (n=15) were transferred separately into sterile container (one larvae/ container) containing maize leaf bits of early vegetative (15-20 days old seedling), vegetative stage (35-45 days old plant) and tassels (50-60 days old plant) and reared until pupation (n=10). Fresh food was provided regularly as per needs. Male and female longevity were observed with their release in a rearing cage with 10% honey provided and replenished daily as food. Duration of larval instars, prepupa, pupa, adult and preoviposition period were observed. Pairs up to 48 hr after emergence were used to study the adult phase, and longevity. The head capsule of the larvae of all the instars formed after each moult were collected and stored in 70% ethanol. The head capsule width was observed and measured under Leica stereozoom microscope (M205C) with version LAS4.0 image analyzer. Head capsule measurement data were analyzed as per McClellan and Logan (1994), in which analysis of plot of mean instar sizes against a presumed instar number. Summary statistics and linear regression was calculated using Microsoft Excel 2007.

Prestarved and pre-weighed third and fifth instar (n=20) were transferred to containers with 10g leaves of 15-20 day old maize @ one larva/ container. The larvae were reared to the subsequent instar. Fresh food was provided regularly. Observations made daily included bodyweight of larva and weight of excreta after 24 hr/ larva using electronic balance (Model No. PGB 630). The following nutritional indices were calculated as per Waldbauer (1968) and Scriber and Slansky (1981).

1. Consumption index (CI): $CI = \frac{F}{TA}$
2. Approximate digestibility (AD): $AD = \frac{F-E}{F} \times 100$
3. Efficiency of conversion of ingested food in to body matter (ECI): $ECI = \frac{G}{F} \times 100$
4. Efficiency of conversion of digested food into body matter (ECD): $ECD = \frac{G}{F-E} \times 100$

Where, F = Fresh weight of food eaten (g), T = Duration of the feeding period (days), A = Mean fresh weight of larvae during feeding period (g), G = Fresh weight gain of larvae during feeding period (g), E = Weight of excreta (g). The biology data were subjected to variance analysis and means compared by Tukey test through SPSS software. Data referring to the growth rate (cephalic capsule width) were analyzed through linear regression (p=0.05).

RESULTS AND DISCUSSION

Biology: The results are presented in Table 1. The eggs were laid in egg masses and the number of eggs/ mass was about 150-200. Eggs were laid one over the other in two to four layers on the surface of the leaves preferably on the dorsal side; these were pale white to creamish covered with greyish white scales; turned brown to black just before hatching; egg period ranged from 2-3 days. Larvae were pale green to dark brown with longitudinal stripes; third instar were characterized by an inverted Y-shape yellow coloured epiricanial suture on the head and it became prominent in the late instar; there were six distinct instars over a period of 14-19 days. Characteristically the *S. frugiperda* larva can be identified by the arrangement of dorsal setae in a typical square shaped arrangement on the VIII abdominal segment. Comparing the duration of each larval instar between maize growth stages; viz; early vegetative stage (15 days), vegetative stage (35-45 days), flowering stage (50-60 days), no significant difference was observed in late instars. But in early instars significant difference in duration was found. The early larval instars were shorter on early vegetative stage compared with the late ones. Similarly, Pannuti et al. (2015) reported that maize leaves developed during reproductive phase are not suitable for early instar development, but silk, tassel and kernel tissues in the reproductive phase had a positive effect on survival and development. The pupae were orange brown, changed to dark reddish brown with time; pupal period was about 8-11 days (9.56± 1.12). Kalyan et al. (2020) reported the pupal period as 8.96 days. Male adults closely resemble *S. litura*. Female moth had brown forewing with less distinct triangular markings. Hind wings were straw coloured with a dark brown margin. The total lifecycle of male and female ranged from 33-46 and 35-47 days, respectively. The female survived for 10.10 days with a range of 9-12 days compared to male (8.1 days) with a range of 7-10 days. No significant difference in duration of adult male and female life cycle was observed. Similarly, Deole and Paul (2018) reported that adults longevity was within 5-7days and the total lifecycle was completed in 28-35 days.

Morphometrics: Table 1 provides the larval head capsule width, and larvae when reared on maize variety Co H-6 passed through six instars; head width was 0.34, 0.60, 0.89, 1.32, 1.86 and 2.36 mm for first to sixth instars, respectively; thus, the head width fell into six well defined instars. Linear regression analysis showed significant relationship between larval instars and head capsule width (Y= 0.408x-0.202, R^2=0.0979). Dyar (1890) stated that the width of head capsule of lepidopterous larvae was more or less constant for given instar of a given species; also the successive larval instars of a given species showed more or less regular geometrical progression in the growth of head capsule. Dyar's ratio for laboratory populations of *S. frugiperda* were 1.76, 1.48, 1.48, 140, 1.26 for the first to last instars, respectively. The present study indicated that *S. frugiperda* had six larval instars and showed that the head capsule width (exuvia) is useful in separating the instars. These results on the head capsule width agree with those observed by Bailey and Chada (1968) for *S.frugiperda* fed with sorghum grain. Also, these corroborate with those found by Machado et al. (1985) working with *S.frugiperda* fed with kale.

Santos et al. (2002) studied the cephalic capsule width of *S. frugiperda* in different corn genotypes and recorded values similar to those of this study with linear

Table 1. Biology and nutritional indices of *S frugiperda* on maize

Stage of insect	Biology when fed with maize leaves obtained from different phases of growth						Geometric growth ratio using head capsule width as a parameter			Nutritional indices on maize			
	Early vegetative stage (15 days old seedling)		Vegetative stage (35-45 days old plant)		Flowering stage (50-60 days old plant)								
	Range (days)	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range (mm)	Mean ± SD	Geometric progression/ Dyar's ratio	CI	AD	ECI	ECD
Incubation period	2-3	2.45 ±0.46	2-3	2.40 ± 0.40	2-3	2.34 ± 0.45							
Larva 1st Instar	2-3.5	2.42 ± 0.49^{a}	2-3	2.63 ± 0.48^{ab}	2-3	2.91 ± 0.50^{b}	0.32 -0.37	0.34 ± 0.01	1.76	-	-	-	-
2nd Instar	2-3	2.34 ± 0.40^{b}	2-3.5	2.40 ± 0.52^{ab}	2-4	2.54 ± 0.73^{a}	0.52 -0.67	0.60 ± 0.05	1.48	-	-	-	-
3rd Instar	1-2.5	1.74 ± 0.38^{ab}	1-2	1.60 ± 0.47^{b}	1-2	1.90 ± 0.35^{a}	0.82-0.96	0.89 ± 0.04	1.48	2.30	35.70	18.33	51.3
4th Instar	2-3	2.36 ± 0.48	1-3	2.06 ± 0.69	2-3	2.42 ± 0.47	1.29 -1.38	1.32 ± 0.03	1.40	-	-	-	
5th Instar	3-4	3.56 ± 0.48	3-5	3.72 ± 0.75	3-5	3.88 ± 0.72	1.81-1.93	1.86 ± 0.04	1.26	2.31	40.29	12.21	30.0
6th Instar	4-5	4.42 ± 0.49^{ab}	4-6	4.76 ± 0.72^{a}	3-6	4.08 ± 0.90^{b}	2.10 -2.60	2.36 ± 0.16	-	-	-	-	-
Pupa	8-11	9.0 ± 1.15	8-11	9.56 ± 1.12	8-12	9.2 0 ± 1.04	-	Mean geometric progression	1.48	-	-	-	-
Adult male	7-9	7.8 ± 0.81	7-9	7.7 ± 0.77	8-10	8.8 0 ± 0.81	-	-	-	-	-	-	-
Adult female	9-12	10.52 ± 1.08	9-12	9.92 ± 1.11	9-11	9.88 ± 0.83	-	-	-	-	-	-	-

Mean followed by the same letter in the line do not differ statistically by the Tukey test (p=0.05) regression value of 0.998. Similar results were reported by Manjula et al. (2019) in *S. frugiperda* but for fifth and sixth instars, values were higher. Hutchinson and Tongring (1984) argued that Dyar's rule might result from a maximization of growth efficiency, assuming that the size of the first instar, the number of instars and the arithmetic mean of growth ratios are predetermined. Several factors such as parasitism (Jobin et al., 1992), temperature, food availability, locality, and rearing regimes may affect growth rates and morphometrics, either between populations or between individuals of the same population (Daly, 1985). However, the approximate constancy of growth ratios can as well be seen as resulting from the physiological base of moulting (Sehnal,1985). Dyar's hypothesis (1890) indicates that mean head capsule widths follow a geometrical succession in lepidopteran larval development. Dyar's theory may have more notoriety than utility, as it applies in some cases but not in others (Hutchinson and Tongring, 1984). Although Dyar's rule is strongly debated in lepidopteran head capsule analysis, the theory as well support the six instars of the FAW

Nutritional indices: The results for nutritional indices of third and fifth instars of *S. frugiperda* are given in Table 1; these reveal that the CI and AD values increased as larva aged, while ECI and ECD were inversely related. These results agree with those of Firake and Behere (2020). Because of physiological and behavioral changes (Nation, 2000) the feeding period of fifth instar was lower than third and subsequently nutritional responses of these two larval instars were different. In the present study, AD, the percentage of food ingested and effectively assimilated by the insect, had lower percentages than those registered by Busato et al. (2002). The ECI and ECD are the general indices of an insects ability to use the food consumed for overall development and the efficiency of conversion of digested food in to growth, respectively (Nathan et al., 2005). Higher ECI and ECD values in third instar indicate their ability to cause higher damage to maize plants. But ECI and ECD values was found lower in fifth instars. Similar results were given by Firake and Behere (2020) when reared on maize and ginger. Deviation might be possible due to the age of the larva in a particular stadium at the time of weighing, as reported by Naseri et al. (2010).

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