**A REVIEW ON BIOLOGY OF FALL ARMYWORM, *Spodoptera frugiperda* ON MAIZE**

**L. S. CHAUDHARY 1, C. J. PATEL 2, H. G. PATEL3, K. V. CHAUDHARY4 and D. S. RABARI 5**

1. **Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari- 396 450 Gujarat, India**

**Email address** **lalabhai261999@gmail.com** **and Mobile no. 8511421905**

1. **ASPEE Shakilam Biotechnology Institute, Navsari Agricultural University Surat-395 007 Gujarat, India**

**Email address** **cjpatel@nau.in** **and Mobile no. 9725006536**

1. **Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari- 396 450 Gujarat, India**

**Email address** **hiralpatel6078@gmail.com** **and Mobile no. 9723695936**

1. **Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari- 396 450 Gujarat, India**

**Email address** **kirpalchaudhary8808@gmail.com** **and Mobile no. 8141567029**

1. **Department of Entomology, N M College of Agriculture, Navsari Agricultural University, Navsari- 396 450 Gujarat, India**

**Email address** **dsrabari@nau.in** **and Mobile no. 8511680714**

**ABSTRACT**

The female laid eggs in masses (150-200 eggs/mass) on the under or upper surface of the maize leaf, lid of glass jar and also in whorls. The egg mass was covered with a layer of scales some time, not covered with scales. The incubation, larval, pre-pupal and pupal period were 2 to 3, 13.5 to 23, 2 to 3 and 5 to 8 days, respectively under laboratory condition. The first, second, third, fourth, fifth and sixth instar period were from 2 to 3, 2 to 3, 2 to 3, 2 to 3, 3 to 4 and 3 to 5 days respectively. The last instar larva was dark brown with reddish brown head marked with inverted ‘Y’ shape on the head with the elevated distinct dark coloured black spots (Pinacula) on the whole body which bears spines and arrangement of the dorsal pinacula the four black spots arranged in square on the 8th abdominal segment. The forewing of male adult was light brown, grey and straw. Markings on the male were more pronounced than the female with males having a grey colour and a light diagonal marking on the forewing. While female forewing was uniform greyish brown to a fine mottling of grey and brown. The life cycle of male and female were 28 to 41 days and 30 to 45 days, respectively.

**Keywords:** Fall armyworm, *Spodoptera frugiperda,* Maize

**INTRODUCTION**

The name “fall armyworm” originates from their nature of the damage, where infestations sometimes resemble as an army, as they move across large agricultural fields and earned their common name by eating all plant matter, they encounter in their wide dispersals, like a large army (Smith, 1797). Due to its migratory behaviour, the fall armyworm is known as a sporadic pest. A new invasive pest, fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) attained the status as a major pest resulting in extensive yield losses of maize all over the world. FAW is a devouring pest native to tropical and subtropical regions of America where it was first detected in 1797 and first discovered in the African continent in 2016 (Goergen *et al.,* 2016) and has reached China, spreading across Africa and Asia continents, west to east, in just three years. Entry of this destructive insect into a portion of Asia is questionable because a majority of people inhabit there and in locations nearby and already a huge pressure is created on food production systems. In India, the occurrence and prevalence of this invasive pest were noticed for the first time by Sharanabasappa *et al.* (2018) from Karnataka state which is the first reported infestation in Asia, in July 2018. Subsequently, it spread into the other ten states of India till the middle of March 2019. Later, its existence was confirmed in the states of Maharashtra, Gujarat and Chhattisgarh (Chormule *et al*., 2019; Sisodiya *et al.,* 2018; Deole and Paul, 2018). It is a cosmopolitan pest of the maize crop (Wiseman *et al*., 1966). The fall armyworm may travel over 500 km before they start oviposition (Prasanna *et al*., 2018). The study of the biology of fall armyworm as occurring in Gujarat is very much important for identifying the life stages and finding out the weaker stage of the pest which provides the basis for management strategies. Farmers are growing a wide variety of commercial hybrids across the state, but the hybrids with good plant vigour and genetic resistance to crop pests were most preferred to combat the invasive alien insect pests. The use of insect-resistant cultivars is an important component of Integrated Pest Management (IPM) which provides an economic, stable and environmentally sound approach to minimize damage from borer pests (Rasool *et al.,* 2017). Keeping this in view present studies were carried out.

### **Egg Stage**

The gravid female laid eggs in clusters on the under or upper surface of the maize leaf, lid of glass jar and also in whorls. The eggs were dome shaped, dorsoventrally flattened, initially pale green later turned to golden yellowish and finally to black. The egg mass was covered with a layer of scales some time, not covered with scales observed by Siddhapara *et al.* (2021), Ramzan *et al.* (2021), Ahmad *et al*. (2021), Manjula *et al*. (2019), Sharanabasappa *et al.* (2018), Sisodiya *et al.* (2018) and Rajisha *et al. (*2022). The eggs were laid in egg masses comprised of 150-200 eggs/mass noticed by Rajisha *et al. (*2022). The average fecundity per female was 939 eggs recorded by Vishwakarma *et al. (*2020). The incubation period of eggs as 2 to 3 days noted by Kranthi *et al.* (2022), Ashok *et al.* (2020), Vishwakarma *et al.* (2020), Ahmad *et al*. (2021), Sharanabasappa *et al.* (2018), Rajisha *et al.* (2022) and Kranthi *et al.* (2022). Kalyan *et al.* (2020) recorded incubation period of eggs as 3-4 days with an average of 3.30 days. The eggs were 0.47 to 0.59 mm in diameter recorded by Manjula *et al*. (2019) and Ipsita and Sahu(2020).

### **Larva Stage**

#### **First instar**

The first instar larvae of fall armyworm were green in colour with a black head showed by Assefa (2018), Deole and Paul (2018), Sisodiya *et al.* (2018) and Sharma *et al.* (2022). The larvae that they were very tiny and completely devoured the egg shells from which they hatched. Comparatively large flattened circular black head and a whitish body covered with minute hairs noticed by Kalyan *et al.* (2020). The duration of first instar larvae ranged from 2.00-3.00 days with a mean of 2.6±0.51 days noted by Reddy *et al*. (2021) and more or less similar with Vishwakarma *et al.* (2022). The duration of first instar was 5 days recorded by Manjula *et al*. (2019). The body length was 1.68±0.00 mm and width was 0.14±0.26 mm of first instar larvae recorded Ahmad *et al*. (2021). The body Length and width of first instar larvae were 1.42±0.28 mm and 0.28±0.06 mm, respectively (Reddy *et al*., 2021). Larva measured 0.71 mm in length and with 0.16 mm head capsule width recorded by Manjula *et al*. (2019). The mean head capsule width was 0.33 mm, whereas, body length and width were 1.67 mm and 0.33 mm respectively by reported by Vishwakarma *et al.* (2022).

#### **Second instar**

The second instar larvae had amber coloured head and a pale white to yellowish coloured body with a tinge of brown on the dorsum. The body also developed faint white dorsal and sub-dorsal lines at this stage exhibited by Kalyan *et al. (*2020), Kalyan *et al.* (2020) and Bhavani *et al.* (2019). The no. of setae per segment varied between 2-4 observed by Vishwakarma *et al. (*2020). The duration of second instar larvae ranged from 2.00-3.00 days with a mean of 2.7 ± 0.48 days reported by Reddy *et al*. (2021). The length and width of second instar larvae were 3.81 mm and width 1.14 mm, respectively recorded by Vishwakarma *et al*. (2022). The mean length and width of second instar larvae were 3.32±0.48 mm and width 0.69±0.04 mm, respectively noted by Reddy *et al*. (2021). Sharanabasappa *et al.* (2018) found the head capsule width of second instar larvae was 0.48±0.01 mm. The head capsule width was 3.5 to 4 mm whereas length was about 0.5 mm (Manjula *et al*., 2019) and Sharanabasappa *et al.* (2018) recorded the larval head capsule width was 0.48±0.01 mm.

#### **Third instar**

The third instar larvae had immense change in body colour, changed from pale white to greenish brown. The dorsal and sub-dorsal white lines were plainly visible and the black spots became prominent showed by Kalyan *et al. (*2020). The 3rd instar was brownish with two to three whitish dorsal lines (Ahmad *et al*., 2021 and Sharma *et al.,* 2022). The characterized by an inverted Y-shape yellow coloured epiricanial suture on the head revealed by Rajisha *et al. (*2022). The third instar larval period was 2.20±0.41days and range was 2-3 days noted by Vinay *et al.*, (2022). The third instar larval duration was 1.48 days recorded by Vishwakarma *et al*. (2022). the 3rd instar larval period of 1.95±0.20 days on the sorghum host and 2.00±0.05 days on the maize hosts (Keerthi *et al.,* 2021). The body length and width were 6.68±0.14 mm and 0.82±0.03 mm, respectively recorded by Siddhapara *et al. (*2021), Sharma *et al.* (2022) and Vishwakarma *et al*. (2022). The average length of 3rd instar was 7.12 mm (6.4-7.8 mm) and width of head capsule was 0.8 mm (0.80±0.004) recorded by Sharma *et al.* (2022). The head capsule width was 0.50±0.01 mm (Ahmad *et al*., 2021).

#### **Fourth instar**

The body colour of fourth instar larvae varied from olive brown to dark brown. The dorsal and sub-dorsal white lines also became conspicuous observed by Kalyan *et al. (*2020). It was clearly seen inverted ‘Y’ shaped marking on the head and four black spots arranged in square on the dorsal surface of 8th abdominal segment noticed by Reddy *et al. (*2020). All the spots arranged as in case of third instar with increase in size and with more darkness reported by Manjula *et al*. (2019). The duration of fourth instar larvae ranged from 2.00-3.00 days with a mean of 2.4±0.51 days noted by Reddy *et al. (*2020) and Reddy *et al*. (2021). The body length and width were measured 13.94±1.09 mm and 0.84±0.02 mm, respectively recorded by Siddhapara *et al. (*2021). The average length was 11.6 mm (9.4-13.5 mm) and width of head capsule was 1.37±0.006 mm measured by Sharma *et al., (*2022).

#### **Fifth instar**

The fifth instar larvae body was yellowish to cream. Colour of the head was brick red with dark brown areas. Thoracic and abdominal segments are similar in colour. The area around the hair was black ring in first thorax only. In remaining segments, black ring and lighter area was present. Light dorsal longitudinal lines became lighter. The side areas were brown in colour observed by Manjula *et al.* (2019) and Igyuve *et al.* (2018). Black tubercles with spines were found on the dorsal side of the body (Reddy *et al.,* 2020). The duration of fifth instar larva varied from 3 to 4 days with an average of 3.05±0.05 days recorded by Tiwari and Deole (2021); Rajisha *et al.* (2022) and Reddy *et al.* (2020). The mean body length and width were 18.81 mm and 3.45 mm, respectively (Vishwakarma *et al*., 2022). The average length of 5th instar was 18.51 mm (15.8-22.5 mm) and width of head capsule was 2.11 mm reported by Sharma *et al. (*2022). Vishwakarma *et al*. (2022) recorded the mean body length and width were 18.81 mm and 3.45 mm, respectively.

#### **Sixth instar**

The sixth instar larva as dark brown with reddish brown head marked with inverted ‘Y’ shape on the head with the elevated distinct dark coloured black spots (Pinacula) on the whole body which bears spines (long primary setae). The arrangement of the dorsal pinacula the four black spots arranged in square on the 8th abdominal segment. Large spots especially on 9th segment had a typical arrangement in a trapezoidal pattern and also seen from 1 to 7th abdominal segments (Babu *et al.,* 2019; Sharanabasappa *et al.*, 2018; Manjula *et al*., 2019; Reddy *et al*., 2021 and Vinay *et al.,* 2022). The duration of 3.67±0.83 days of sixth instar larval period which varied from 3-5 days reported by Reddy *et al. (*2020) and Vishwakarma *et al.* (2022). The mean length and width of sixth instar larvae were 33.6±1.67 mm and 5.90±0.26 mm, respectively noticed by Reddy *et al*., (2021) and Vishwakarma *et al.* (2022). Ahmad *et al*. (2021) reported that length and width of larva were 26.98±2.93 and 3.90±0.00 mm, respectively. The average length of 6th instar larva was 34.39 mm (28.3-38.8 mm) and width of head capsule was 2.7 mm noted by Sharma *et al. (*2022).

#### **Total larval period**

The total larval period varied from 13.5 to 23 days with an average of 18.25 days recorded by Vishwakarma *et al. (*2020). Sharanabasappa *et al.* (2018); Bhavani *et al.* (2019); Manjula *et al*. (2019) and Vishwakarma *et al.* (2020) noted the total larval duration was 14-19, 13-14, 14-30 and 13.5 to 23 days, respectively.

### **Pre-pupa Stage**

The pre-pupal period during, the full-grown larva stopped feeding, turned greenish and the bright brown colour revealed by Sharanabasappa *et al.* (2018); Bhavani *et al.* (2019) and Vishwakarma *et al*. (2022). The pre-pupal stage duration was varied from 2 to 3 days with an average of 2.10±0.06 days recorded by Tiwari and Deole (2021 and Kranthi *et al.,* 2022). The length of the pre-pupae ranging from 19 to 22 mm with an average of 20.0±0.11 mm while the breadth ranged from 2.7 to 3.2 mm with an average of 3.08±0.02 mm observed by Tiwari (2020).

### **Pupa Stage**

The newly formed pupae were green in colour. After 12-14 hours pupae were converted dark reddish brown in colour stated by Deole and Paul (2018). The pupation was occurred in the maize stem or between the leaf-cutting or sides of Petri dishes observed by Ahmad *et al*. (2021). Sisodiya *et al.* (2018) and Babu *et al.* (2019) noted reddish brown colour with cremaster in pupa. Ahmad *et al*. (2021) mentioned important morphological characteristic that obtect type of pupa was whitish green. The duration of pupal stage varied from 5 to 8 days with an average of 6.30±0.14 days (Tiwari and Deole, 2021). Sharanabasappa *et al.* (2018) recorded the pupal duration period was 9 to 12 days. The distance between genital opening and anal slot recorded more in case of female (0.89±0.01 mm) than the male (0.43±0.01 mm) recoded by Siddhapara *et al*. (2021). Length and width of male and female pupa were 14.12±0.38, 14.00±0.32 and 4.12±0.12, 4.00±0.00, respectively (Ahmad *et al*., 2021 and Vishwakarma *et al*., 2022)). The average weight of pupa was 18.9 mg (15-24 mg) weighted by Sharma *et al.* (2022). Gamil (2020) recorded 9.56 days pupal duration and the pupal weight was 0.3033 gm, while the normal pupae, malformed pupae, pupal mortality and emergence per cent was 95.44, 4.56, 4.0, and 96.0 per cent, respectively.

**Adult Stage**

#### **Male**

The forewing of male adult was light brown, grey and straw. Markings on the male were more pronounced than the female with males having a grey colour and a light diagonal marking on the forewing. The back wings were white concluded by Deole and Paul (2018). Sisodiya *et al.* (2018) revealed the greyish brown male adults; forewings grey and brown shaded with oval or oblique orbital spots, triangular white patch near apical margins of the forewing. Damasia *et al*. (2020) observed the male adults as greyish brown, forewings grey and brown shaded with oval orbital spots, triangular white patch near apical margins of the forewing. Sharanabasappa *et al.*, (2018) revealed that male adult survived for 8.20 days with a range of 7-9 days and average wingspan of was 3.25 cm with a range of 3.00 to 3.50 cm in male. The mean body length of the male moths was 15.20±1.30 mm (Reddy *et al.*, 2021).

#### **Female Adult**

The forewings of females were uniform greyish brown to a fine mottling of grey and brown. The hind wing was silver-white with a narrow dark border in both male and female (Sharanabasappa *et al.*, 2018; Reddy *et al.*, 2021 and Sharma *et al.,* 2022). The female body length was 10.13±0.56 mm and wing expanse was 31.00 ±1.43 mm measured by Ahmad *et al*. (2021). The female adult survived for 9-12 days with an average of 10.80 days (Sharanabasappa *et al.*, 2018). Manjula *et al*. (2019) revealed 1.2 cm forewing length, 0.9 cm hind wing length and 3.0 to 3.1 cm wing span. Ahmad *et al*. (2021) reported that the female body length was 10.13±0.56 mm and wing expanse was 31.00 ±1.43 mm. The average weight of adult female 3.3 mg and wingspan of female was measured as 3.2 cm reported by Sharma *et al.,* 2022).

### **Pre-oviposition, Oviposition and Post-oviposition Period**

The pre-oviposition period of female moths of *S. frugiperda* varied from 3 to 4 days with an average of 3.05±0.05 days, however oviposition period was 1 to 2 days with an average of 1.85±0.08 days reported by Tiwari and Deole (2021). The post-ovipositional period ranged from 4 to 6 days with an average of 4.40±0.51 days recorded by Reddy *et al.* (2021). Gamil (2020) stated that the mean time required for maturation of the ovaries and starting to egg-laying (pre-oviposition period) was 3.50 days. Moreover, oviposition and post-oviposition period were 5.11 and 2.61 days, respectively. Vishwakarma *et al.* (2020) observed the mean pre-oviposition, oviposition and post-oviposition period as 3.5, 3.5 and 3.5 days and it ranged from 3-4, 2-5 and 3-4 days, respectively. Keerthi *et al.* (2021) revealed that the pre-oviposition period on sorghum and maize was 3.87±0.52 and 3.71±0.45 days, respectively whereas, oviposition period on sorghum and maize was 3.10±0.62 and 3.05±0.52 days. Siddhapara *et al.* (2021) noted the pre-oviposition, oviposition and post oviposition period was of 3.50±0.51, 3.20±0.89 and 3.90±0.71 days, respectively.

### **Life Span**

The total life cycle of *S. frugiperda* occupied on an average of 33.1±0.69 days ranging from 28 to 41 days in case of male, while 36.0±0.75 days ranging from 30 to 45 days in case of female observed by Tiwari and Deole (2021). Vinay *et al.* (2022) reported 38.10±6.51 days total duration of fall armyworm life cycle. Ahmad *et al*. (2021) noticed 35.32±4.02 and 42.00±5.76 days for average total life cycle of male and female, respectively. Sharanabasappa *et al.* (2018) reported total life cycle of male and female ranging from 32-43 and 34-46 days, respectively. Kalyan *et al.* (2020) revealed 36.15 and 40.11 days to complete total life cycle of male and female, respectively.

### **Sex Ratio**

The sex ratio of fall armyworm at constant conditions in the laboratory was approximately 1:1.23 (45.24 male:55.76 female) recorded by Gamil (2020). Siddhapara *et al.* (2021) calculated the sex ratio which was 1.13:1 (female: male). Sharma *et al.* (2022) worked out the adult male to female sex ratio as 1:1.30.

### **Fecundity**

The fecundity of 1004.65±110.00 eggs and range were 820-1150 eggs/female recorded by Ahmad *et al*. (2021). Reddy *et al.* (2021) reported that the egg laying capacity of female varied from 855-1172 eggs with an average of 1015±115.48 eggs. Sharanabasappa *et al.* (2018) reported that the average fecundity/female was 1064.80±109.53 eggs which ranged from 835-1169 eggs. Siddhapara *et al.* (2021) noticed 1145.43±182.15 eggs/female (766 to 1389 eggs). Tiwari and Deole (2021) noticed that egg laying capacity of female varied from 536 to 579 eggs with an average of 557.2±2.81 eggs. Sharma *et al.* (2022) revealed 979.43±24.086 eggs average fecundity and the range was 713 to 1166 eggs.

### **Hatchability**

The extent of egg hatching in the rage of 72.00-95.54 per cent reported by Siddhapara *et al.* (2021). Vinay *et al.* (2022) found the hatching of eggs was about 96.26 per cent. Sharanabasappa *et al.* (2018) reported 96.60±1.43 percent egg hatchability which ranged from 95-98 per cent. Gamil (2020) recorded the hatchability in fall armyworm and it was observed 97.33 per cent.

**CONCLUSION**

 The gravid female laid eggs in 150-200 eggs/mass on the under or upper surface of the maize leaf, lid of glass jar and also in whorls and egg mass covered with a layer of scales some time, not covered with scales. The incubation, larval, pre-pupal and pupal period were 2 to 3, 13.5 to 23, 2 to 3 and 5 to 8 days, respectively under laboratory condition. The newly formed pupae were green in colour. After 12-14 hours pupae were converted dark reddish brown in colour, The forewing of male adult was light brown, grey and straw. While female forewing was uniform greyish brown to a fine mottling of grey and brown. The hind wing of adults was whitish colour.

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