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Biology and Morphometry of Gram Pod Borer *Helicoverpa armigera* Hubner Infesting Gram *Cicer arietinum* L.

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Authors' contributions

This work was carried out in collaboration among all authors. Author PNP Designed, performed the experiment, analyzed the data, and visualized the manuscript, author MKJ. Wrote, reviewed, edited the manuscript, and visualized the data, author PBP. Supervised the work and visualized the data. All authors have read and approved the manuscript.

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ABSTRACT

Aims: To investigate the biology and morphometry of gram pod borer *Helicoverpa armigera* Hubner infesting gram *Cicer arietinum* L.
Place and Duration of Study: The investigation was conducted in the PG Research Laboratory, Department of Entomology, Navsari Agricultural University, Navsari, Gujarat, India under laboratory conditions at 26.7±1.66˚C temperature and 51.11±6.35 per cent relative humidity during 2021-22.
Methodology: The *Helicoverpa armigera* was reared from eggs to the adult stage under laboratory conditions. Twenty-five samples of eggs, larval instars, pre-pupa, pupa, and adults were used for morphometrics measurement and fifty samples of each stage were used for determining the biological parameters.
Results: The *Helicoverpa armigera* female laid eggs singly or in batches of 2 to 3 during nighttime. The incubation period was 2.84±0.58 days with 58.39±4.22 per cent hatching. The larvae passed through six different instars having durations, 2.54±0.50, 4.04±0.88, 4.04±0.88, 4.24±0.77,

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4.50±0.51, and 4.92±0.80 days of first, second, third, fourth, fifth, and sixth instars, respectively. The mean larval, pre-pupal, pupal, pre-oviposition, oviposition, and post-oviposition periods were 23.12±1.83, 1.64±0.69, 13.40±1.25, 2.60±0.49, 6.94±0.82, and 1.62±0.49 days, respectively. The lengths of egg, first, second, third, fourth, fifth, and sixth instar larvae, prepupa, pupa, and male and female adults, were 0.49±0.05, 1.56±0.12, 4.27±0.38, 8.47±0.70, 13.50±0.95, 21.84±0.97, 32.58±0.99, 25.03±0.97, 19.95±0.96, 17.25±0.56, and 20.32±0.95mm, respectively. Whereas, the breadths were 0.50±0.04, 0.46±0.03, 0.72±0.04, 2.45±0.03, 2.72±0.07, 3.22±0.11, 4.12±0.16, 3.88±0.39, 5.26±0.31, 34.44±1.09, and 39.86±1.03mm, respectively. The lengths of head capsules of first, second, third, fourth, fifth, and sixth instar larvae were 0.23±0.01, 0.45±0.01, 0.63±0.02, 1.12±0.01, 2.19±0.02, and 2.61±0.04, respectively which was not studied before. Whereas, the breadths were 0.26±0.01, 0.50±0.01, 0.73±0.01, 1.28±0.01, 2.22±0.01, and 2.70±0.05, respectively. The sex ratio of male to female was 1:0.76±0.05. The fecundity of gravid females was 544.85±63.89 eggs/female. The adult longevity was 9.04±0.78 and 10.54±0.99 days in males and females, respectively. The total life span was recorded as 47.20±2.57 and 48.70±2.79 days in males and females, respectively

Conclusion: The *Helicoverpa armigera* adults completed their life cycle in 43 to 56 days. The adult longevity was higher in females than males. The males were smaller than the females. The sex ratio was male-biased. The various biological parameters would be useful in the planning of integrated management strategy under field conditions.

Keywords: Biology; gram; helicoverpa armigera; laboratory condition; morphometrics.

1. INTRODUCTION

Gram, *Cicer arietinum* L., is considered the “King of Pulses” and belongs to the family Fabaceae. It probably originated from South and Eastern Turkey [1]. Globally, gram is grown over an area of 14.84 million hectares with a production of 15.08 million tons and a productivity of 1016 kg per ha. India ranks first in the area and production of gram among all the gram-producing countries of the world. In India, gram is grown over 10.95 million hectares area with a production of 11.08 million tons and a productivity of 1012 kg per ha [2]. Gram crops are vulnerable to the attack of more than 60 insect pests right from germination to maturity [3]. Among these insect pests, the gram pod borer *Helicoverpa armigeras* (Hubner) is the most serious one [4]. *H. armigera* is a polyphagous pest. Besides gram, it can also infest cotton, pigeon peas, tomato, sorghum, cowpea, groundnut, okra, peas, field beans, and soybeans [5]. It is considered a national pest due to its high fecundity, high adaptability to diverse agro-climatic conditions, migratory behavior, and development of resistance capability against various insecticides [6]. The larvae of *H. armigera* are foliage feeders as early and later instars move to the developing seeds and fruits leading to a drastic reduction in yield. In India, the extent of losses due to *H. armigera* is up to 27.9 per cent in the North West Plain Zone, 13.2 per cent in the North East Plain Zone, 24.3 per cent in the Centre Plain Zone, and 36.4 percent in the South Plain Zone [7]. Knowledge of the biology of *H. armigera* is essential to know the life history and habits of this pest for finding out the most vulnerable stage during life span which helps in developing suitable management strategies. The various biological characters also help in the proper identification of the pest. Therefore, the investigation was conducted to study the biology and morphometrics of *H. armigera* under laboratory conditions.

2. MATERIALS AND METHODS

The present investigation was carried out in the PG Research Laboratory, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India during 2021-22.

The initial culture of *H. armigera* larvae was collected from the unsprayed Gujarat Gram-2 (GG-2) grown field at the college farm, N. M. College of Agriculture, and reared under laboratory conditions at 26.7±1.66˚C and 51.11±6.35 per cent relative humidity at the PG Research Laboratory, Department of Entomology, Navsari Agricultural University, Navsari. For the rearing of larvae, gram leaves and pods were placed in a Petri dish (90mm). Full-grown larvae were provided with moistened soil for pupation in a one-litre glass jar and the top of the jar was covered with a piece of muslin cloth and held in position with the help of a rubber band. After pupation, it was sorted out

and kept in a glass jar for the emergence of adults. The newly emerged male and female moths' separation was done based on morphological characteristics and they were released in pairs in glass jars (150mm diameter; 200mm height) for mating. The tender shoot of gram was placed in a glass jar with a moist cotton to maintain turgidity and it was changed daily to provide a natural condition for oviposition. The adults were fed with honey solution (5%) soaked on cotton pads in small plastic caps placed inside the jar and replaced daily. The lid of the jar was covered with a black-colored muslin cloth. Eggs were collected daily in the morning from the leaves, shoots, black-colored muslin cloth, and also from the bottom of the cage and kept in a Petri dish for hatching. Different stages of development were judged by the following method.

2.1 Egg

To determine the incubation period, 50 eggs were collected and placed in the Petri dish individually with the help of a fine camel hairbrush. To determine the length and breadth of eggs, 25 eggs were observed. The size of eggs was measured under the stereo-trinocular microscope (Make: Olympus. SZ 61) fitted with a Brand Catcum-130 camera having software Power Scope Photo (Version 3.1). To study the incubation period, counted numbers of freshly laid eggs were observed daily till hatching. The hatching percentage was calculated from the data on the number of eggs hatched out of the total number of eggs kept for hatching. When the larva hatched, it was provided with a sufficient number of leaves and tender shoots of a gram.

2.2 Larva

The newly hatched larva was transferred individually with the help of a fine camel hairbrush in a Petri dish having fresh leaves and pods of gram. The individual Petri dish having larvae was observed daily. Food for larvae was changed every day in the morning. To determine the larval instars, the individual larva was observed daily for the shedding off of exuviae as well as a head capsule by the larva. The molting was confirmed by the presence of a casted-off head capsule. The duration of each larval instar was determined by recording days between two moultings. Observations on the size of larvae were recorded for each instar. Length and breadth of initial instar larvae and head capsules were measured under the stereo-trinocular microscope (Make: Olympus. SZ 61) fitted with Brand Catcum-130 camera having software Power Scope Photo (Version 3.1). While length of late instar larvae was measured with the help of a ruler (scale). Observations on the total larval period were recorded. The total larval period was considered based on the date of egg hatching to the date of initiation of the pre-pupal stage.

2.3 Pre-Pupa and Pupa

To know the pre-pupal period, observations were taken every day in the morning hours. During the larval development, the full-grown larvae stopped feeding and turned greenish before entering the pre-pupal stage. In this stage, larvae constructed the cocoon from moist soil and pre-pupated inside it. The duration between the formation of pre-pupae to the formation of pupae was recorded as the pre-pupal period. The time interval between the formation of a pupa to the emergence of an adult was considered the pupal period. Measurements were taken for the length and breadth of pre-pupae at its initial stages. After the formation of a cocoon, it was broken and pupae were taken out from it. Measurements regarding the length and breadth of pupae were also recorded with the help of a ruler (scale).

2.4 Adult

Adults that emerged from pupae were observed for their color, shape, size, and sex differences. The male and female moths were measured across their expanded wings with the help of a ruler (scale). The female was distinguished from the male by various morphological characteristics *viz,* the female moth was bigger than the male and the forewings of the male moth were greenish-gray in color. Whereas, the forewings of the female moth were orange-brown and the female also had a broad abdomen with a tuft of creamish scales at the tip of the abdomen.

2.5 Pre-Oviposition, Oviposition, and Post-Oviposition Period

To determine the pre-oviposition period, the newly emerged pairs of adults (male and female) were kept separately in a rearing cage. The period between the emergence of an adult female and commencing the egg-laying was recorded as the pre-oviposition period. The period between commencing the egg-laying and ceasing of egg-laying by an individual female was recorded as the oviposition period and the period between the ceasing of egg-laying to the

death of the female was considered as post-oviposition period.

2.6 Fecundity

Eggs laid by female moths were collected and counted daily in the morning. The total number of eggs laid during the life span of a female moth was considered as its fecundity.

2.7 Adult Longevity

The male and female longevity was calculated separately from the date of emergence to the death of adults.

2.8 Sex Ratio

To determine the sex ratio (male: female), the emerged male and female were identified based on morphological features, and the sex ratio was worked out.

2.9 Total Life Cycle

The duration of the entire life span was considered as the period between the date of egg-laying and the date of death of adults.

3. RESULTS AND DISCUSSION

3.1 Egg

In field conditions, *H. armigera* females laid eggs singly on the tender part of the plant but in the laboratory, they laid eggs in groups and sometimes singly or in batches of 2 to 3 eggs at night. Eggs were mostly laid on cotton swabs followed by tender shoots of the gram, black-colored muslin cloth tied over the jar, and the surface of the glass jar (Photo 1a to d). More or less similar observations were also noticed by Ali et al. [8] who observed that female moths of *H. armigera* laid eggs singly on chickpeas during nighttime due to nocturnal behaviour. Sharma et al. [9] recorded that female moths of *H. armigera* laid eggs on the leaf and shoots of a tomato plant, pot surface, and black-colored muslin cloth and also from the bottom of an oviposition cage in the laboratory.

The freshly laid eggs were yellowish white and glistening at first, but changed to dark brown after a day and became dark black just before hatching (Photo 1e-f). Eggs were hemispherical with flat bases and prominently sculptured in the form of longitudinal ribs running from one polar end to another polar end. The infertile eggs soon became conical in shape and the day after it shriveled up. The present observations are more or less similar to the results of Ali et al. [8], Sharma et al. [9], and Baikar and Naik [10].

Data on morphometrics of the eggs in Table 1 revealed that the length of eggs varied from 0.41 to 0.60mm with a mean of 0.49±0.05mm, while the breadth of eggs varied from 0.43 to 0.56mm with a mean of 0.50±0.04mm. The results are more or less confirmed with the findings of Ali et al. [8] who observed that egg size was 0.42 to 0.60mm in length and 0.40 to 0.55mm in breadth. The eggs measured 0.49±0.04mm in length and 0.52±0.18mm in breadth [9].

The data in Table 2 revealed that the incubation period of *H. armigera* eggs varied from 2 to 4 days with a mean of 2.84±0.58 days. The present findings are supported by those of Gadhiya et al. [11] who observed that the incubation period of *H. armigera* eggs varied from 2 to 4 days on groundnut. According to Baikar and Naik [10], the incubation period of *H. armigera* eggs varied from 2 to 4 days on chilli which is also similar to the present findings.

The mean hatching percentage was 58.39±4.22%. However, the minimum egg hatching of fifty per cent and the maximum egg hatching of sixty-five per cent were recorded (Table 2). The present findings are more or less similar to the findings of Ali et al. [8] who recorded that the hatching percentage of *H. armigera* eggs ranged from 51 to 55 per cent with a mean of 53.33 on chickpeas. While, Gadhiya et al. [11], observed that the hatching percentage of *H. armigera* ranged from 50 to 75 per cent with a mean of 59.40±6.56 on groundnut. Differences might be due to the impact of climatic conditions.

3.2 Larva

During the present experiment, it was revealed that larvae underwent six instars and formed the pupal stage. The body of freshly emerged larvae (first instar) was semi-translucent and dirty white (Photo 2a). Thoracic and anal shields were black. Zig-zag spotted lines were present on the dorsal side and black-colored spiny structures came out from those spots. The above findings are supported by Ali et al. [8] who reported that the newly hatched larva was yellowish-white with a black colour head capsule. The newly hatched larva was semitranslucent and creamy in color

recorded by Herald and Tayde [12]. Furthermore, after hatching neonate larvae fed on chorion (Photo 2b) and later on fed on tender leaves of a gram by scrapping. Almost similar observations were made by Dahegaonkar and Mohite [13] who noted that newly hatched larvae typically consumed their egg shells.

It was evident from the data in Table 1 that the length of first instar larvae ranged from 1.32 to 1.80mm with a mean of 1.56±0.12mm, while the breadth varied from 0.41 to 0.50mm with a mean of 0.46±0.03mm. The present findings are more or less in conformation with the findings of Ali et al. [8] who reported that the length and breadth of the first instar of *H. armigera* larvae were 1.40±0.06 and 0.45±0.01mm. Rabari et al. [14] observed that the length and breadth of the first instar of *H. armigera* larvae were on average 1.52±0.04 and 0.49±0.01mm. The head capsule of the first instar of *H. armigera* was black (Photo 2c). The length of the head capsule varied from 0.21 to 0.24mm with a mean of 0.23±0.01mm while, the breadth of the head capsule varied from 0.25 to 0.27mm with a mean of 0.26±0.01mm (Table 1). The results are more or less confirmed by Gadhiya et al. [11] who noticed that the head capsule breadth of first instar larvae was 0.25 to 0.29mm with a mean of 0.28±0.01mm. Baikar and Naik [10] revealed that the head capsule breadth of first instar larvae was 0.20 to 0.29mm with a mean of 0.25±0.03mm. This is the first report about the head capsule length of first instar larvae. The duration of first instar larvae was varied from 2 to 3 days with a mean of 2.54±0.50 days (Table 2). Similar observations were recorded by Ali et al. [8] that the first instar larval period was 2.27±0.08 with a range of 2 to 3 days on chickpeas. Similarly, Baikar and Naik [10] noticed that the first instar larval period lasted 2 to 3 days with a mean of 2.4±0.52 days on chilli. Herald and Tayde [12] observed that the first instar larval period was 2.50±0.52 with a range of 2 to 3 days on tomato.

Morphologically, the second instar larvae resembled the first instar larva. Larvae were yellowish to light brown (Photo 3a). Thoracic legs were darker in color as compared to the abdominal legs. Setae was noted all over the body of the larva and also on the head capsule. It was more active than the previous instar. The above findings are supported

1a: Singly laid egg

1b: Eggs in batches

1c: Eggs laid on plant part of gram

1d: Eggs laid on a moist cotton swab

1e: Eggs one day after ovipostion

1f: Eggs just before hatching

Photo 1. Eggs of *Helicoverpa armigera*

Table 1. Morphometrics of different life stages of *Helicoverpa armigera* on gram

Stages	Length (mm)			Breadth (mm)		
	Min.	Max.	Mean±S.D.	Min.	Max.	Mean±S.D.
Egg	0.41	0.60	0.49 ±0.05	0.43	0.56	0.50±0.04
First instar						
Larvae	1.32	1.80	1.56±0.12	0.41	0.50	0.46±0.03
Head capsule	0.21	0.24	0.23±0.01	0.25	0.27	0.26±0.01
Second instar						
Larvae	3.54	4.89	4.27±0.38	0.66	0.80	0.72±0.04
Head capsule	0.44	0.46	0.45±0.01	0.48	0.52	0.50±0.01
Third instar						
Larvae	7.21	9.82	8.47±0.70	2.39	2.51	2.45±0.03
Head capsule	0.61	0.66	0.63±0.02	0.71	0.75	0.73±0.01
Fourth instar						
Larvae	10.80	16.19	13.50±0.95	2.62	2.85	2.72±0.07
Head capsule	1.10	1.14	1.12±0.01	1.26	1.30	1.28±0.01
Fifth instar						
Larvae	18.78	23.83	21.84±0.97	3.04	3.42	3.22±0.11
Head capsule	2.16	2.22	2.19±0.02	2.20	2.24	2.22±0.01
Sixth instar						
Larvae	29.30	34.70	32.58±0.99	3.87	4.37	4.12±0.16
Head capsule	2.55	2.66	2.61±0.04	2.64	2.78	2.70±0.05
Prepupa	21.77	28.08	25.03±0.97	3.23	4.48	3.88±0.39
Pupa	17.62	21.49	19.95±0.96	4.11	4.15	4.13±0.02
Adult						
Male (wing expanded)	16.35	18.39	17.25±0.56	32.67	36.78	34.44±1.09
Female (wing expanded)	18.38	22.12	20.32±0.95	38.66	42.01	39.86±1.03

n=25

2a. Larva on gram leaf **2b. Larva fed on cocoon** **2c. Head capsule**

Photo 2. First instar larva of *Helicoverpa armigera*

by Ali et al. [8] who reported that second-instar larvae were reddish brown with black color head capsules. The length of larvae varied from 3.54 to 4.89mm with a mean of 4.27±0.38mm while, the breadth of larvae varied from 0.66 to 0.80mm with a mean of 0.72±0.04mm (Table 1). Ali et al. [8] reported that the length of the second instar ranged from 3.50 to 5.00mm with a mean of 3.88±0.11mm, while the breadth varied from 0.70 to 0.80mm with a mean of 0.75±0.01mm. Sharma et al. [9] noticed that the larvae measured varied from 3.37 to 5.96mm with a mean of 4.32±0.58mm in length and 0.63 to 0.86mm with a mean of 0.77 ± 0.06mm in breadth. The head capsule was light black transparent with some spots present on it (Photo 3b). The length of the head capsule varied from 0.44 to 0.46mm with a mean of 0.45±0.01mm while, the breadth of the head capsule varied from 0.48 to 0.52mm with a mean of

0.50±0.01mm (Table 1). The results are more or less confirmed by Gadhiya et al. [11] who noticed that the head capsule breadth of second-instar larvae was 0.47 to 0.55mm with a mean of 0.51±0.02mm. Baikar and Naik [10] revealed that the head capsule breadth of second instar larvae was 0.46 to 0.54mm with a mean of 0.50 ± 0.03mm. There was no evidence in the past about the head capsule length of second-instar larvae. The duration of the second instar varied from 2 to 4 days with a mean of 2.88±0.69 days (Table 2). According to Gadhiya et al. [11], the mean duration of the second instar larva of *H. armigera* was 2.80 ± 0.76 days with a range of 2 to 4 days. Similar observations were taken by Rabari et al. [14] who observed that the duration of the second instar larvae was 2 to 4 days with a mean of 2.67±0.66 days.

The third instar larvae (Photo 4a) were larger compared to the second instar larvae. The color of the body was greenish to light brown, but it was darker than the previous instar. Thoracic legs were dark black. Elevated distinct dark-colored black spots (Pinacula) were present on the whole body, which bore spines (long primary setae). The arrangement of the dorsal pinacula *i.e.,* the four black spots arranged in a straight line on three thoracic segments while it was arranged in a square on the eighth abdominal segment. Furthermore, it had a typical arrangement in a trapezoidal pattern from the first to seventh abdominal segments and had an inverted trapezoidal pattern on the ninth abdominal segment. The dorsal longitudinal line was prominent on either side of the third instar. Moreover, a white-colored band was present on the lateral side of the body. The above findings are supported by Herald and Tayde [12] who reported that the third instar larvae were yellowish brown and the head was somewhat darker in color compared to the body. The length of the third instar larvae varied from 7.21 to 9.82mm with a mean of 8.47±0.70mm, while the breadth varied from 2.39 to 2.51mm with a mean of 2.45±0.03mm (Table 1). These findings are similar to the findings of Ali et al. [8] who reported that the length and breadth of the third instar larvae varied from 7.00 to 9.50mm with a mean of 7.90±0.19mm, while the breadth varied from 2.00 to 2.50mm with a mean of 2.28±0.04mm on chickpea. Whereas, Sharma et al. [9] observed that the larvae measured varied from 7.13 to 9.96mm with a mean of 8.28 ± 0.69mm in length and 1.24 to 1.68mm with a mean of 1.40 ± 0.14mm in breadth when reared on tomato. Differences might be due to the impact of climatic conditions or different hosts.

Table 2. Duration of different life stages of *Helicoverpa armigera* on gram

Particulars	Min.	Max.	Mean ± S.D.
Incubation period (Days)	2.00	4.00	2.84 ± 0.58
Hatching (%)	50.00	65.00	58.39 ± 4.22
Larval period (Days)			
First instar	2.00	3.00	2.54±0.50
Second instar	2.00	4.00	2.88±0.69
Third instar	3.00	5.00	4.04±0.88
Fourth instar	3.00	5.00	4.24 ± 0.77
Fifth instar	4.00	5.00	4.50 ± 0.51
Sixth instar	4.00	6.00	4.92 ± 0.80
Total	20.00	28.00	23.12 ± 1.83
Pre-pupal periods (Days)	1.00	3.00	1.64 ± 0.69
Pupal period (Days)	11.00	15.00	13.40 ± 1.25
Pre-oviposition period (Days)	2.00	3.00	2.60 ± 0.49
Oviposition period (Days)	6.00	8.00	6.94 ± 0.82
Post-oviposition period (Days)	1.00	2.00	1.62 ± 0.49
Sex ratio (Male: Female)	0.67	0.84	0.76 ± 0.05
Adult longevity (Days)			
Male	8.00	10.00	9.04 ± 0.78
Female	9.00	12.00	10.54 ± 0.99
Total life cycle (Days)			
Male	43.00	53.00	47.20 ± 2.57
Female	43.00	56.00	48.70 ± 2.79
Fecundity (No. of egg/female)	424.00	631.00	544.85 ± 63.89

n=50

3a. Larva

3b. Head capsule

Photo 3. Second instar of *Helicoverpa armigera*

4a. Larva

4b. Head capsule

Photo 4. Third instar of *Helicoverpa armigera*

The head capsule of the third instar larvae was more compact and light orange with light brown spots (Photo 4b). The length of the head capsule varied from 0.61 to 0.66mm with a mean of 0.63±0.02mm while, the breadth of the head capsule varied from 0.71 to 0.75mm with a mean of 0.73±0.01mm (Table 1). The present data are corroborated with the findings of Gadhiya et al. [11] who observed that the head capsule breadth of the third instar larvae was 0.66 to 0.75mm with a mean of 0.70±0.03mm. Baikar and Naik [10] reported that the head capsule breadth of third-instar larvae was 0.60 to 0.70mm with a mean of 0.64±0.03mm. There was no evidence in the past about the head capsule length of third-instar larvae. The data presented in Table 2 indicated that the duration of the third instar larvae varied from 3 to 5 days with a mean of 4.04±0.88 days. The present findings are exactly similar to Gadhiya et al. [11] who revealed that the mean development time of the third instar was 4.16±0.69 days with a range of 3 to 5 days. Sharma et al. [9] observed that the duration of the third instar larva was 3 to 5 days with a mean of 4.12±0.72 days.

The fourth instar larvae had a reddish-brown head and the color of the body was yellowish to light brown, but it was darker than the previous instar (Photo 5a). The arrangement of the dorsal pinacula was similar to the previous instar. Setae was noted all over the body of the larva and also on the head capsule. Dorsal stripes were either continuous or broken and lateral stripes were yellowish-white in colour. The present observations are in close agreement with the reports of Sharma et al. [9] and Herald and Tayde [12]. The length of larvae varied from 10.80 to 16.19mm with a mean of 13.50±0.95mm while, the breadth of larvae varied from 2.62 to 2.85mm with a mean of 2.72±0.07mm (Table 1). The present findings agreed with the results of Ali et al. [8] who reported that the length and breadth of the fourth instar larva varied from 10.25 to 16.50mm with a mean of 12.83±0.45mm, while the breadth varied from 2.60 to 3.00mm with a mean of 2.85±0.04mm on chickpea. Sharma et al. [9] noticed that the larva measured varied from 12.38 to 15.48mm with a mean of 13.81 ± 0.89mm in length and 2.23 to 2.76mm with a mean of 2.44±0.17mm in breadth

when reared on tomato. The head capsule was similar to the third instar but the size differed and the color was also darker than the previous instar (Photo 5b). The length of the head capsule varied from 1.10 to 1.14mm with a mean of 1.12±0.01mm while, the breadth of the head capsule varied from 1.26 to 1.30mm with a mean of 1.28±0.01mm (Table 1). The present data are corroborated by the findings of Gadhiya et al. [11] who revealed that the head capsule breadth of the fourth instar larvae was 1.12 to 1.30mm with a mean of 1.25±0.04mm. Baikar and Naik [10] noticed that the head capsule breadth of fourth instar larvae was 1.10 to 1.26mm with a mean of 1.16±0.05mm. There was no evidence in the past about the head capsule length of fourth instar larvae. The data presented in Table 2 indicated that the duration of fourth instar larvae varied from 3 to 5 days with a mean of 4.24±0.77 days. The present findings agree with the results of Baikar and Naik [10] who revealed that the duration of fourth instar larvae was 4 to 5 days with a mean of 4.30±0.48 days. Rabari et al. [14] observed that the duration of the fourth instar larvae was 3 to 5 days with a mean of 3.97±0.72 days.

The fifth instar larvae showed a greenish brown and pinkish brown color pattern with broken dorsal stripes and continuous white lateral stripes (Photo 6a). The arrangement of the dorsal pinacula was similar to the previous instar. Setae were noted all over the body of the larva and also on the head capsule. Legs were pale green. The fifth instar larvae were more active and aggressive as compared to the previous stage but at the time of molting, larva was less active. The results were more or less confirmed by Dahegaonkar and Mohite [13] who noted that the color of larvae was brownish green and the head was brown with fine pale setae. Herald and Tayde [12] reported that the color of larvae was apparent having dorsal side pale yellow with grayish longitudinal lines. Similarly, Sharma et al. [9] noticed that the fifth instar larvae indicated a pale green color pattern with broken dorsal stripes and continuous lateral stripes. The fifth instar larvae were more active and aggressive as compared to the previous stage. The length of larvae varied from 18.78 to 23.83mm with a mean of 21.84±0.97mm while, the breadth of larvae varied from 3.04 to 3.42mm with a mean of 3.22±0.11mm (Table 1). These findings are similar to the findings of Ali et al. [8] who observed that the length and breadth of the fifth instar larva varied from 18.00 to 25.00mm with a mean of 20.97±0.61mm, while the breadth varied from 3.10 to 3.55mm with a mean of 3.25±0.04mm on chickpea. Likewise, Sharma et al. [9] reported that the larva measured varied from 19.38 to 21.94mm with a mean of 20.92±0.58mm in length and 3.04 to 3.46mm with a mean of 3.24±0.08mm in breadth when reared on tomato.

The head capsule of the fifth instar larvae was transparent and light orange (Photo 6b). The microscopic view showed that a mandible had six teeth on the front side of the head capsule which were not visible to the naked eye (Photo 6c). The length of the head capsule varied from 2.16 to 2.22mm with a mean of 2.19±0.02mm while, the breadth varied from 2.20 to 2.24mm with a mean of 2.22±0.01mm (Table 1). The results are more or less confirmed by Gadhiya et al. [11] who observed that the head capsule breadth of the fifth instar larva was 2.55 to 2.63mm with a mean of 2.60±0.02mm. Baikar and Naik [10] reported that the head capsule breadth of the fifth

5a. Larva

5b. Head capsule

Photo 5. Fourth instar of *Helicoverpa armigera*

6a. Larva **6b. Head capsule** **6c. Head capsule showing mandible (six teeth)**

Photo 6. Fifth instar of *Helicoverpa armigera*

instar larva was 2.40 to 2.50mm with a mean of 2.45±0.03mm. Differences might be due to the impact of climatic conditions or changes in the location of the study. There was no evidence in the past about the head capsule length of fifth instar larvae. The data presented in Table 2 indicated that the duration of fifth instar larvae varied from 4 to 5 days with a mean of 4.50±0.51 days. The present findings are exactly similar to those of Baikar and Naik [10] who revealed that the duration of the fifth instar larvae was 4 to 5 days with a mean of 4.50±0.53 days. Sharma et al. [9] observed that the duration of the fifth instar larvae was 3 to 5 days with a mean of 4.40±0.50 days.

The sixth instar larvae (Photo 7a) looked flattened ventrally but appeared convex dorsally. This instar showed color polymorphism and it was green, light greenish, reddish brown, or greenish brown with black longitudinal stripes on the dorsal side and continuous white stripes were present on the lateral side. The arrangement of pinacula was similar to the preceding instar. Setae were noted all over the body of the larva and also on the head capsule. Legs were light green. Characteristics of larva during moulting were similar to the preceding instar. The present observations are in close agreement with Ali et al. [8] who reported that the full-grown larva was straw yellow to green with lateral brown strips. The tubercles and spiracles of the larva were also brown to black, giving them a spotted appearance. Dahegaonkar and Mohite [13] noted that the larva was flattened ventrally but convex dorsally. The full-grown sixth instar larva had a reddish-brown head. Short white bristles were scattered all over the body. Larva showed more pronounced individual variations like markings. They exhibited body color polymorphism. It can be seen from Table 1 that the length of the sixth instar larvae ranged from 29.30 to 34.70mm with a mean of 32.58±0.99mm, while the breadth varied from 3.87 to 4.37mm with a mean of 4.12±0.16mm. The present findings are more or less in conformation with the findings of Ali et al. [8] who noticed that the length and breadth of the sixth instar larvae varied from 30.50 to 34.50mm with a mean of 32.50±0.35mm, while the breadth varied from 3.80 to 4.25mm with a mean of 4.03±0.04mm on chickpea. Whereas, Sharma et al. [9] observed that the larvae measured 25.45 to 30.34mm with a mean of 27.71±1.44mm in length and 3.97 to 4.50mm with a mean of 4.11±0.13mm in breadth when reared on tomato. The variations might be due to different hosts, on which they were reared.

The head capsule of the sixth instar larvae was similar in appearance to that of the fifth instar larvae but differed in size and was observed with attached to the exuviae (Photo 7b). The length of the head capsule varied from 2.55 to 2.66mm with a mean of 2.61±0.04mm while, the breadth of the head capsule varied from 2.64 to 2.78mm with a mean of 2.70±0.05mm (Table 1). The results are more or less confirmed by Baikar and Naik [10] who revealed that the head capsule breadth of sixth instar larva was 2.70 to 2.90mm with a mean of 2.76±0.06mm. There was no evidence in the past about the head capsule length of sixth instar larvae. It was evident from data in Table 2 that the duration of the sixth instar larvae varied from 4 to 6 days with a mean of 4.92±0.80 days. The results are more or less confirmed by Baikar and Naik [10] who revealed that the duration of sixth instar larvae was 4 to 5 days with a mean of 4.20±0.42 days. Sharma et al. [9] observed that the duration of sixth instar larvae was 4 to 6 days with a mean of 4.84±0.74 days.

The perusal of data presented in Table 2 revealed that the total larval developmental

period of *H. armigera* varied from 20 to 28 days with a mean of 23.12±1.83 days when reared on gram. The present results are supported by Baikar and Naik [10] who revealed that the total larval developmental period of *H. armigera* varied from 21 to 23 days with a mean of 21.8±0.79 days when reared on chilli. Rabari et al. [14] noted that the total larval developmental period of *H. armigera* varied from 20 to 26 days with a mean of 22.97±1.10 days when reared on gram. Sharma et al. [9] recorded that the total larval developmental period of *H. armigera* varied from 20 to 26 days with a mean of 23.20±1.73 days when reared on tomato. The variations might be due to different environmental conditions or different host insect nutrition.

3.3 Pre-Pupa

The full-grown larvae before pupation passed through a pre-pupal stage. In this stage, the final instar larva stopped feeding and changed its color from pinkish brown to light pinkish brown and light green to pale green with less prominent dorsal stripes (Photo 8). The full-grown larvae wandered on the soil surface for pupation and then moved below the soil surface for pupation and pupated within the soil by making an earthen cocoon (Photo 9). During this period, larvae did not exhibit any movement unless it was disturbed. Finally, larvae shedded the exuviae, and the head capsule attached to them entered into the cocoon and went into the pupal stage. The present results are supported by Ali et al. [8] who reported that in the pre-pupal stage, the full-grown larvae became sluggish, and wrinkled with suspended feeding and movement. The pre-pupa was noticed as light green-yellowish but later on, it turned to dark brown. Baikar and Naik [10] noted that the full-grown larva before pupation passed through a pre-pupal stage, stopped feeding, gradually shrunk in length, and became sluggish. Dahegaonkar and Mohite [13] observed that during this time larval activity decreases. Once feeding was completed, larvae moved below the soil surface to pupate.

The length of the pre-pupa varied from 21.77 to 28.08mm with a mean of 25.03±0.97mm, while the breadth varied from 3.23 to 4.48mm with a mean of 3.88±0.39mm (Table 1). The present findings are more or less similar to the results of Ali et al. [8] who depicted that the length of the pre-pupa varied from 22.50 to 29.00mm with a mean of 25.43±0.49mm while the breadth varied from 3.90 to 5.00mm with a mean of 4.56±0.09mm. Gadhiya et al. [11] reported that the length of the pre-pupa varied from 21.50 to 26.80mm with a mean of 24.12±1.58mm while the breadth varied from 2.70 to 4.30 mm with a mean of 3.51±0.52mm. The differences might be due to different environmental conditions or due to different hosts used for the study. The pre-pupal period (Table 2) was found to range from 1 to 3 days with a mean of 1.64±0.69 days during the present study. The pre-pupal duration varied from 1 to 3 days with a mean of 2.15±0.16 days reported by Ali et al. [8], 1 to 3 days with a mean of 1.93 ± 0.69 days noted by Rabari et al. [14], 1 to 2 days with a mean 1.48 ± 0.50 days observed by Sharma et al. [9], which are more or less in conformation with the present findings.

3.4 Pupa

Pupation was observed mostly in the soil within the earthen cocoon (Photo 9). Newly formed pupae were light green (Photo 10a) and after some time they became hard and changed their color from light green to reddish brown with prominent black eye spots seen after a few hours. The pupae were obtect type and the surface of the pupa was smooth, cylindrical, and broadly rounded anteriorly and tapering posteriorly with a pair of cremaster. The abdomen was distinctly marked into ten segments and a well-defined dark brown pair of spiracles were visible on the pro-thoracic segment and from the 2nd to 8th abdominal segment (Photo 10b). Male and female pupae were differentiated at the pupal stage based on morphometric characters. Distance between the genital opening and anal slot could be used to distinguish the female and male pupa. Male pupa had genital aperture on the ninth abdominal segment while, in the case of females, it was on the eighth abdominal segment. Distance between the genital opening and anal slot was recorded more in the case of females than males (Photo 10c and Photo 10d). Movement of the abdomen was observed when the pupa was disturbed. The present observations are more or less similar to Ali et al. [8] who reported that the pupae were of obtect type with reddish brown colour. The surface was smooth and it rounded both anteriorly and posteriorly, with two tapering parallel spines at the posterior tip. Dahegaonkar and Mohite [13] observed that pupae were obtect type, broadly rounded anteriorly and tapering posteriorly. Its head and thorax were pale green in the beginning but they became light brown within 20 – 24 hrs. Herald and Tayde [12] noted that the pupae were of the obtect type with mahogany-brown color. The surface was smooth and broadly rounded at the anterior but tapering at the posterior.

7a. Larva

7b. Head capsule

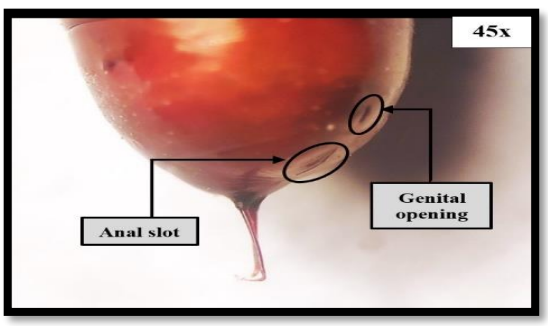
Photo 7. Sixth instar of *Helicoverpa armigera*

Photo 8. Pre-pupa of *Helicoverpa armigera*

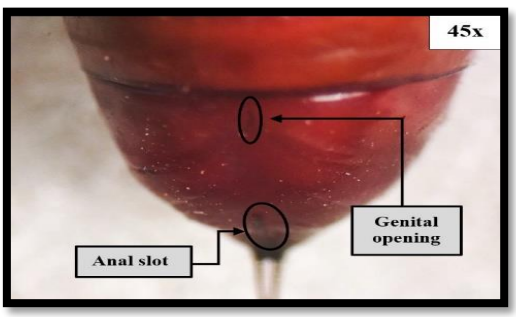
Photo 9. Earthen cocoon of *H. armigera* pupa

10a. Freshly formed pupa

10b. Later stage pupa



10c. Male pupa



10d. Female pupa

Photo 10. Pupae of *Helicoverpa armigera*

The length of the pupae varied from 17.62 to 21.49mm with a mean of 19.95±0.96mm while the breadth varied from 4.74 to 5.75mm with a mean of 5.26±0.31mm (Table 1). The present findings are more or less similar to the results of Ali et al. [8] who depicted that the length of the pupae varied from 17.00 to 20.50mm with a mean of 19.00±0.30mm while the breadth varied from 5.40 to 6.30mm with a mean of 5.72±0.08mm. Dahegaonkar and Mohite [13] noted that the average length and breadth of pupa varied from 20.64±0.64 and 5.37±0.08mm, respectively. Herald and Tayde [12] reported that the length of the pupae varied from 18.50 to 22.20mm with a mean of 19.67±1.31mm while the breadth of pupae varied from 4.80 to 5.30mm with a mean of 5.10±0.14mm. The differences might be due to different environmental conditions or due to different hosts used for the study.

Looking at the data in Table 2, it can be seen that the duration of the pupal stage varied from 11 to 15 days with a mean of 13.40±1.25 days. The present findings are more or less similar to the results of Ali et al. [8] who reported that the pupal duration varied from 10 to 14 days with a mean of 13.15±0.27 days, 13 to 15 days with a mean of 13.8±0.84 days noted by Baikar and Naik [10], 11 to 15 days with a mean 13.48±1.29 days observed by Sharma et al. [9], which are more or less in conformation with the present findings.

3.5 Adult

Compound eyes of freshly formed adult *H. armigera* moths were light green and located laterally on the head. It possessed a pair of setaceous antennae on the dorsal side of the head between the compound eyes. The siphoning type of mouthpart was coiled and rested beneath the head. The adult moth was stout-bodied with a broad thorax. Legs were long with dirty white showing a scaly appearance. Forewings had a series of dots on the margins and a black kidney-shaped marking in the middle underside of each forewing. The transparent membranous part of the forewings was covered with creamy colored scale. However, the hind wings were lighter in colour with a broad dark brown band at the apical end and strongly marked veins. There was a distinguished color pattern between male and female moths. Males were recorded greenish gray, whereas, females with orange-brown and were also identified by the presence of a tuft of hairs on the tip of the abdomen. The adult male moth was smaller than the female moth (Photo 11 and 12). The present findings are in complete agreement with the findings of Ali et al. [8], Sharma et al. [9], Baikar and Naik [10], Herald and Tayde [12], and Dahegaonkar and Mohite [13].

Data on morphometrics of adult *H. armigera* in Table 1 revealed that the length of male varied from 16.35 to 18.39mm with a mean of 17.25±0.56mm and wing expanse varied from 32.67 to 36.78mm with a mean of 34.44±1.09mm. In the case of females, the length varied from 18.38 to 22.12mm with a mean of 20.32±0.95mm and the wing expanse varied from 38.66 to 42.01mm with a mean of 39.86±1.03mm. The results about the adult length and wing expanse are more or less similar to those of Ali et al. [8] who reported that the length and breadth (with wing expanded) of male moths ranged from 16.50 to 18.50mm with a mean 17.65±0.18mm and 32.00 to 37.00mm with a mean 34.73±0.59mm, respectively. Whereas, the length and breadth (with wing expanded) of female moths were 18.25 to 21.50mm with a mean of 20.08±0.38mm and 38.50 to 43.00mm with a mean of 40.93±0.55mm, respectively. Gadhiya et al. [11] revealed that the length and breadth (with wing expanded) of female moths ranged from 17.90 to 22.50mm with a mean of 21.09±1.28mm and 37.60 to 42.10mm with a mean of 40.77±1.68mm, respectively and in case of male moth, it was 16.40 to 18.50mm with a mean of 17.55±0.52mm in length and 31.70 to 36.50mm with a mean of 34.62±1.49mm in breadth. Rabari et al. [14] noticed that the length and breadth (with wing expanded) of male moths ranged from 16.24 to 19.56mm with a mean of 17.42±0.85mm and 31.48 to 37.45mm with a mean of 34.18±1.57mm, respectively. The female moth was 18.26 to 21.66mm with a mean of 20.36±0.83mm in length and 36.21 to 42.26mm with a mean of 40.78±1.26mm in breadth (with wing expanded).

3.6 Adult Longevity

Male adult longevity varied from 8 to 10 days with a mean of 9.04±0.78 days, while in the female it varied from 9 to 12 days with a mean of 10.54±0.99 days (Table 2). Studies on adult longevity are more or less similar to the report of Ali et al. [8] who observed that the longevity of male and female moth of *H. armigera* varied from 7 to 11 days with a mean 9.1±0.42 days and 10 to 14 days with a mean 11.74±0.51 days, respectively. Sharma et al. [9] revealed that

longevity ranged from 9 to 10 days with a mean of 9.50±0.53 days in males, while longevity of female moths ranged from 10 to 13 days with a mean of 11.35±0.86 days.

3.7 Pre-Oviposition, Oviposition, and Post-Oviposition Period

Looking at the data in Table 2, it can be seen that the pre-oviposition period varied from 2 to 3 days with a mean of 2.60±0.49 days. The findings of the present investigation are in close confirmation with the report of Ali et al. [8] who noted that the pre-oviposition period varied from 2.0 to 2.80 days with a mean of 2.45±0.08 days. Whereas, it was 2 to 3 days on chickpeas reported by Rabari et al. [14], and 2 to 3 days on tomatoes observed by Sharma et al. [9].

The oviposition period varied from 6 to 8 days with a mean of 6.94±0.82 days (Table 2). The present findings are similar to the past report of Gadhiya et al. [11] who noted that the oviposition period varied from 6 to 8 days with a mean of 7.04±0.61 days. Whereas, Rabari et al. [14] revealed that the oviposition period varied from 5 to 8 days with a mean of 5.90±0.88 days. Sharma et al. [9] observed that the oviposition period varied from 4 to 7 days with a mean of 5.80±0.86 days.

Data presented in Table 2 indicated that the post-oviposition period varied from 1 to 2 days with a mean of 1.62±0.49 days. The present findings are agreed with the report of Ali et al. [8] who reported that the post-oviposition period varied from 1.80 to 2.30 days a mean of 2.00±0.05 days. Baikar and Naik [10] revealed that the post-oviposition period varied from 1 to 2 days with a mean of 1.3±0.48 days. Sharma et al. [9] observed that the post-oviposition period varied from 2 to 3 days with a mean of 2.40±0.50 days. Differences might be due to the impact of climatic conditions or changes in the location of the study.

3.8 Fecundity

The fecundity varied from 424 to 631 eggs with a mean of 544.85±63.89 eggs per female (Table 2). In the past, Ali et al. [8] recorded that the fecundity of *H. armigera* varied from 408 to 617 eggs per female in chickpeas. While it was 163 to 318 eggs per female on groundnut [11], 188 to 243 eggs per female on chickpeas [14], and 408 to 617 eggs per female on tomatoes [9]. The differences in fecundity might be due to the impact of climatic conditions or changes in the location of the study.

3.9 Sex Ratio

Based on morphological characters mentioned earlier the adults were differentiated into their sexes. The sex ratio of *H. armigera* varied from 0.67 to 0.84 (Male: Female) with a mean of 1:0.76±0.05 (Table 2). The present findings are more or less agreed with the reports of Dahegaonkar and Mohite [13] who reported that the sex ratio of *H. armigera* was (M: F) 1:0.66. Baikar and Naik [10] noted that the sex ratio of *H. armigera* was 1:0.78 (M: F). Rabari et al. [14] observed that the sex ratio of *H. armigera* was 1:0.87 (M: F).

Photo 11. Adult male of *Helicoverpa armigera*

Photo 12. Adult female of *H. armigera*

3.10 Total Life Cycle

The data in Table 2 indicated that the total life span in males varied from 43 to 53 days with a mean of 47.20±2.57 days while in females varied from 43 to 56 days with a mean of 48.70±2.79 days. The present findings agree with the report of Baikar and Naik [10] who revealed that the total life cycle of *H. armigera* was 42 to 55 days in the case of males, while 44 to 57 days in the case of females. Gadhiya et al. [11] noted that the total life cycle of *H. armigera* occupied 40 to 61 days in the case of males, and 43 to 65 days in the case of females. Sharma et al. [9] observed that the total life span was completed within 48 to 56 days in males, and 49 to 57 days in the case of females. Variations in the findings might be due to different environmental conditions and different hosts used for rearing

4. CONCLUSION

The female *Helicoverpa armigera* laid eggs singly or in batches of 2 to 3 at night. About 58.39±4.22 percent of the laid eggs hatched into larvae after 2.84±0.58 days of incubation. The larva passed through six instars and formed pre-pupa and then pupa in the moist soil. The larval, prepupal, and pupal periods were 23.12±1.83, 1.64±0.69, and 13.40±1.25 days, respectively. The adult males were greenish-gray in color and smaller than the female moth. Whereas, females were orange-brown and identified by the presence of a tuft of hairs on the tip of the abdomen. Adult longevity in males and females was 9.04±0.78 and 10.54±0.99 days. The pre-oviposition, oviposition, and post-oviposition period of adult females were 2.60±0.49, 6.94±0.82, and 1.62±0.49 days, respectively. The sex ratio was male-biased. The fecundity was 544.85 ± 63.89 eggs per female. Moreover, the total life span was recorded as 47.20±2.57 days and 48.70±2.79 days in male and female, respectively. Morphological description of *H. armigera* would be useful in identifying eggs, larvae, pupa, and adults under field conditions. Furthermore, the larval and adult life span and the site of pupation of *H. armigera* would be useful in the planning of integrated management strategy under field conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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