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Biology of *Helicoverpa armigera* (Hubner) on tomato in South Gujarat

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Abstract

Biological studies of *Helicoverpa armigera* carried out on tomato revealed that insect eggs were hemispherical in shape and yellowish white in colour. The incubation period of insect eggs varied from 3 to 5 days indicating 53.18 per cent hatching. The neonate larva looked dirty white which turned to pink brown and pale green at maturity. The larvae passed through six instars wherein their respective durations were of 2.84 ± 0.74 , 3.40 ± 0.50 , 4.12 ± 0.72 , 3.60 ± 0.57 , 4.40 ± 0.50 and 4.84 ± 0.74 days. Total larval period of all the instars was completed in 23.20 ± 1.73 days before undergoing pupation in an earthen cocoon. The pupal period was of 13.48 ± 1.29 days. Male and female moths looked greenish-grey and orange brown, respectively. The female pupa was characterized by presence of tuft of hairs at the tip of the abdomen. Sex ratio (Male: Female) was 1:2.10. The pre, oviposition and post- oviposition periods were of 2.56 ± 0.50 , 5.80 ± 0.86 and 2.40 ± 0.50 days, respectively. The fecundity of insect was 490.20 ± 77.87 eggs laid per female. Adult male and female longevities were of 9.50 ± 0.53 and 11.35 ± 0.86 days, respectively. Total life cycle of male and female insects was completed in 51 ± 2.97 and 53.76 ± 2.43 days, respectively.

Keywords: *Helicoverpa armigera*, biology, tomato, life cycle

1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is a profitable vegetable crop, cultivated widely in South Gujarat. It is also a popular vegetable, globally ranked second in importance to potato (Mandaokar *et al.*, 2000) [7]. In India, the area under tomato cultivation was 7.67 lakh hectare and its production was 16385.00 MT with an average productivity of 21.40 MT/ha during 2014-15 (Anon; 2015) [2]. Though, it is extensively grown all over the country, still the productivity remains low as compared to other countries mainly due to prevalence of insect-pests. Amongst various insect-pests reported in India, as many as sixteen have been observed feeding from germination to the harvesting stage which not only reduce its yield but also deteriorate the quality (Butani, 1997) [3]. The fruit borer, *Helicoverpa armigera* (Hubner) is a highly destructive pest causing serious damage (Krishnamoorthy and Mani, 1996) [6]. It causes damage to the developing fruits which in turn results in yield loss ranging from 20 to 60 per cent (Tewari and Krishnamoorthy, 1984) [13] and up to 90 per cent (Reddy and Reddy, 1999) [10]. Worldwide annual crop loss due to *H. armigera* alone is approximately 5 billion US dollar (Sharma, 2001) [11]. The monetary loss due to this pest in the country has been estimated over rupees one thousand crores per year (Jayraj *et al.*, 1994) [5]. Looking to the importance of tomato crop in general and *H. armigera* in particular under South Gujarat agro-climatic conditions, life cycle of this pest was studied on tomato.

2. Materials and methods

The studies on the biology of the tomato fruit borer, *H. armigera* were conducted under laboratory condition of the Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during 2017.

2.1. Rearing techniques

Larval culture of *H. armigera* was collected initially from tomato field of College Farm, N.M. College of Agriculture, NAU, Navsari and reared on the same crop under laboratory condition till pupation. Larvae were reared individually to avoid cannibalism. Simultaneously, tomato plants were also raised individually in pot for further studies on various aspects of biology of the pest under consideration. Twenty-five sets were maintained in the laboratory for biological studies.

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Newly emerged male and female moths were released in pair in the oviposition cage (20 cm diameter x 45 cm height) for mating. A pot of tomato plant was kept in oviposition cage for females to provide resting and oviposition site. Piece of black colour muslin cloth (1 sq. ft.) was hung in the oviposition cage for egg laying. Oviposition cage was covered with black coloured muslin to create darkness. Cotton swab dipped in five per cent honey solution was kept in small vial and placed in oviposition cage as food to the male and female moths. The eggs were collected using camel hair brush from the leaf, shoots, pot surface, and black coloured muslin cloth and also from the bottom of the cage. Collected eggs were used for further investigation. Simultaneously, a general culture of the pest was also maintained in the laboratory during the study.

2.2. Egg

Colour and morphology of egg was determined with the help of Stereo Trinocular microscope Olympus-SZ (16) fitted with Brand Catcam-130 camera having scope software for measuring size of the egg. Freshly laid 25 eggs were kept separately on tomato leaf on wet cotton piece in Petri dish (10 cm diameter) in each set. The eggs were observed twice a day (8.00 am and 4.00 pm) until the emergence of larvae, thus incubation period was recorded.

2.3. Larva

With a view to determine the number and duration of different larval instars and total larval period, the newly emerged larvae were placed individually in plastic culture tubes (2.5 cm diameter x 7.5 cm height) with the help of fine camel hair brush. A small twig with tender leaves was provided as food to the developing larvae (first and second instar) and end of twig was wrapped with moist cotton swab to maintain turgidity. Thereafter, fresh and tender tomato fruits were provided as food to the larvae to further instars (third, fourth and fifth). The food was replaced on every alternate day. All the larvae in each set were monitored daily for the purpose of recording observation to notice change of instars which was confirmed by presence of casted head capsule and sometimes exuviae in the rearing tube. The duration of each instar was worked out and length as well as breadth of each instar were measured.

2.4. Pre-pupa

About 2.5 to 3.0 cm thick layer of moist soil was provided in the glass jar (10 cm diameter x 13 cm height) to full grown larvae for pupation. To record pre-pupal period, the sixth instar larvae were observed from the time when it stopped feeding and became sluggish to the time when it underwent pupation in the soil.

2.5. Pupa

The pupae were kept in plastic jar (12 cm diameter x 15 cm height). Pupal period was recorded from the time of larva underwent to soil to the emergence of adult. The colour and size of pupae were also recorded.

2.6. Adult

The moths emerged were observed for their colour and size. Male and female moths were differentiated on the basis of presence of tuft of hairs at the end of abdomen in case of female while, it was absent in the male. Twenty-five male and female moths of the same age group were paired separately in oviposition cage to study their pre-oviposition, oviposition and post oviposition periods as well as adult longevity and

fecundity. The length and breadth with their expanded wings were also measured with the help of Vernier caliper. The sex ratio was worked out on the basis of male and female moths emerged from the general culture maintained in the laboratory.

2.7. Pre-oviposition, oviposition and post-oviposition period, fecundity and longevity

Pre-oviposition period was calculated from the date of emergence of female adult to the date of commencement of egg laying. Likewise, period from start of egg laying to the ceasing of laying eggs was considered as oviposition period while the period from ceasing of egg laying to the death of female was considered as post-oviposition period.

2.8. Total life cycle

Total life cycle was considered as the period between dates of egg laying to the date of death of adult insect.

3. Results and Discussion

3.1. Egg

3.1.1. Colour, shape and size

In the present investigation, the freshly laid eggs looked yellowish white in colour, turned to deep yellow after a day and became dark brown prior to hatching. Eggs were hemispherical in shape with flat base and prominently sculptured with numerous ridges running from one polar end to another.

Ali *et al.* (2009)^[1], Patel *et al.* (2011)^[9] and Sharma *et al.* (2011)^[12] reported that *H. armigera* eggs were yellowish white in colour which turned to brown prior to hatching. They further reported that insect eggs looked hemispherical in shape with flat base and numerous edges from one polar to another. These observations were similar to the results observed in the current investigations based on insect colour, shape and size conforming the current investigation.

Size of freshly laid eggs of *H. armigera* indicated 0.41 to 0.57 mm (0.49 ± 0.04) length and 0.26 to 0.89 mm (0.52 ± 0.18) breadth (Table 1). Patel *et al.* (2011)^[9], Sharma *et al.* (2011)^[12] and Gadhiya *et al.* (2014)^[4] indicated length and breadth of freshly laid eggs to the tune of 0.49 ± 0.04 and 0.54 ± 0.02; 0.47 ± 0.04 and 0.48 ± 0.05; 0.47 ± 0.02 and 0.49 ± 0.02 mm, respectively. In the present investigation, length and breadth of freshly eggs were 0.49 and 0.52 mm, respectively which is not too different from the observations recorded by the above workers which conforms the present investigation.

3.1.2. Incubation period

The incubation period of *H. armigera* eggs varied from 3 to 5 days (3.96 ± 0.73). Ali *et al.* (2009)^[1], Patel *et al.* (2011)^[9] and Gadhiya *et al.* (2014)^[4] indicated incubation period of *H. armigera* eggs in the range of 3 to 4, 3 to 5 and 2 to 4 days, respectively which is almost the same as reported in the current investigation (3 to 5 days). Thus, it can be concluded that the above results are said to be in line with those of the above workers

3.2. Larva

3.2.1. Number of larval instars

In order to study the various larval instars of *H. armigera* under laboratory condition, newly hatched larvae were reared individually in plastic culture tube. The larvae passed through six distinct instars, when reared initially on tomato leaves and thereafter on fresh green fruits, till they pupated. Ali *et al.* (2009)^[1] and Patel *et al.* (2011)^[9] reported six instars of *H.*

armigera on chickpea and rose. In the present investigation, six different larval instars of *H. armigera* have been reported which is the same as reported in the above reports thus, conforms the present investigation.

3.2.2. First instar

At the time of hatching, larva came out from the egg by making hole on chorion with the help of mouthparts. The body of freshly emerged larva was semi-translucent and dirty white in colour with whitish longitudinal lines on dorsal surface of the body. Thoracic and anal shields were brown in colour. Thoracic legs were segmented with first two segments light brown and tarsi dark brown to black in colour. Zig-zag spotted line was present on dorsal side and black coloured spiny structure came out from that spot. Freshly emerged larva was yellowish white to reddish-brown in colour on chickpea (Ali *et al.*, 2009) ^[1] while, it was semi-translucent and yellowish on rose (Patel *et al.*, 2011) ^[9].

The newly emerged larva remained sluggish and became active after 2 to 3 hours on leaves. Similar behaviour was observed when the larvae were reared on rose by Patel *et al.* (2011) ^[9]. It was not different when the neonate larvae reared on tomato in the present investigation.

The neonate larva initially remained in egg shell and found to feed on chorion of the egg. Thereafter in search of food, larva was found hanging on petri dish with the help of thread like substance secreted from mouth. Initially, larva was found to feed on tender leaves with its chewing and biting type of mouth parts. The change in instar was confirmed by presence of only head capsule on leaf surface. The exuviae of the whole body was not observed in this instar during the current investigation.

In the current investigation, length of first instar larva varied from 1.34 to 1.82 mm (1.56 ± 0.12) while, breadth varied from 0.19 to 0.36 mm (0.29 ± 0.04) (Table 1). Similarly, length of 1.40 mm and breadth of 0.45 mm of the larval instar was observed on chickpea (Ali *et al.*, 2009) ^[1]. However in another report (Ghadiya *et al.*, 2014) ^[4] on groundnut, length and breadth of the larva was measured as 1.80 mm and 0.31 mm, respectively. The morphometric results obtained in the current investigation (1.56 and 0.29 mm length and breadth, respectively) are more or less the same as obtained by the above workers thus, conforms the experimental findings.

The duration of first instar larva ranged from 2 to 4 days on tomato (2.84 ± 0.74) (Table 2). It was reported to be 2 to 3 days on chickpea (Ali *et al.*, 2009) ^[1], rose (Patel *et al.*, 2011) ^[9] and groundnut (Ghadiya *et al.*, 2014) ^[4]. The results of 2 to 4 days is almost the same as reported by the above workers (2 to 3 days) thus, conforms the present investigation.

3.2.3. Second instar

Morphologically the second instar larva resembled the first instar larva wherein it was yellowish to light green in colour. Thoracic legs were darker in colour as compared to the abdominal legs. It was more active than the previous instar and preferred fresh and tender tomato fruit for feeding.

The larva measured 3.37 to 5.96 mm (4.32 ± 0.58) in length and 0.63 to 0.86 mm (0.77 ± 0.06) in breadth (Table 1). Length and breadth of second instar were 3.88 ± 0.11 and 0.75 ± 0.01 ; 3.43 ± 0.44 and 0.78 ± 0.29 ; 3.52 ± 1.08 and 0.82 ± 0.01 mm, respectively as reported by Ali *et al.* (2009) ^[1], Sharma *et al.* (2011) ^[12] and Patel *et al.* (2011) ^[9].

In the present investigation, duration of the second instar larva ranged from 3 to 4 days (3.40 ± 0.5) (Table 2). Larval period of *H. armigera* was reported to the tune of 2 to 3 days on

chickpea and rose, respectively (Ali *et al.*, 2009 and Patel *et al.*, 2011) ^[1, 9] whereas, it was 2 to 4 days on groundnut (Ghadiya *et al.*, 2014) ^[4]. These reports indicate almost the same results (2 to 4 days) as reported in the current investigation (3 to 4 days) thus, conform the ongoing discussion.

3.2.4. Third instar

The third instar larva was similar to second instar in general appearance but differed in size. The colour of the body was yellowish to light green, but it was darker than the preceding instar. A dorsal longitudinal line was prominent on either side of the third instar.

The length and breadth of the third instar larva varied from 7.13 to 9.96 mm (8.28 ± 0.69) and 1.24 to 1.68 mm (1.40 ± 0.14), respectively (Table 1). Length and breadth of third instar larvae were reported to the tune of 7.90 ± 0.19 and 2.28 ± 0.04 ; 8.30 ± 0.07 and 2.95 ± 0.51 ; 9.74 ± 0.66 and 2.81 ± 0.02 mm, respectively (Ali *et al.*, 2009; Sharma *et al.*, 2011 and Patel *et al.*, 2011) ^[1, 12, 9] which is very close to the results of the current investigation.

In the present investigation, the duration required to complete third instar ranged from 3 to 5 days (4.12 ± 0.72) (Table 2) which was also reported by Ghadiya *et al.*, 2014) ^[4] on groundnut, 2 to 3 days on chickpea (Ali *et al.*, 2009) ^[1] and 2 to 6 days on rose (Patel *et al.*, 2011) ^[9]. Looking to the similarity of results (3 to 5 days) obtained in the current investigation with those of earlier workers (2 to 6 days), the present investigation is said to be in close agreement and may be considered as confirmed.

3.2.5. Fourth instar

The fourth instar larva of *H. armigera* exhibited different colour variations ranging from green to greenish brown. Setae were also observed all over the body. The lateral stripes on all the larvae were yellowish white, but dorsal stripes were of variable colours. The stripes were either continuous or broken.

In the present investigation, the length of the fourth instar larva ranged from 12.38 to 15.48 mm (13.81 ± 0.89), while breadth ranged from 2.23 to 2.76 mm (2.44 ± 0.17) (Table 1). Several reports (Ali *et al.*, 2009; Sharma *et al.*, 2011 and Patel *et al.*, 2011) ^[1, 12, 9] indicated length and breadth of fourth instar as 12.83 ± 0.45 and 2.85 ± 0.04 mm; 17.80 ± 0.34 and 2.99 ± 0.31 mm; 23.02 ± 1.36 and 3.24 ± 0.01 mm, respectively which are more or less the same (13.81 and 2.44 mm) as reported in the present investigation, thus conforms the findings.

In present investigation, the duration of fourth instar larva ranged from 3 to 5 days (3.60 ± 0.57) (Table 2). Larval duration of fourth instar *H. armigera* when reared on chickpea was reported to be 2 to 3 days (2.83 ± 0.07) (Ali *et al.*, 2009) ^[1] while, it was of 3 to 6 days (4.60 ± 0.76) when reared on rose (Patel *et al.*, 2011) ^[9]. These results (2 to 6 days) are more or less the same as obtained in the current investigation (3 to 5 days) thus, conforms the ongoing discussion.

3.2.6. Fifth instar

The fifth instar larva indicated pale green colour pattern with broken dorsal stripes and continuous lateral stripes. The abdomen was yellowish green and thoracic region was dark green in colour at moulting. The fifth instar larva was more active and aggressive as compared to previous stage but at the time of moulting, the larva was less active.

In present investigation, the length and breadth of fifth instar larva ranged from 19.38 to 21.94 mm (20.92 ± 0.58) and 3.04 to 3.46 mm (3.24 ± 0.08), respectively (Table 1). Ali *et al.* (2009) [1] indicated average length and breadth of fifth instar larva of *H. armigera* on chickpea to the tune of 20.97 ± 0.61 and 3.25 ± 0.04 mm, respectively which is similar to the current report (20.92 and 3.24 mm) thus, confirms the current results.

The duration of fifth instar larva ranged from 4 to 5 days (4.40 ± 0.5) (Table 2). Earlier reports (Ali *et al.*, 2009 and Patel *et al.*, 2011) [1, 9] indicated duration of fifth instar larva of *H. armigera* as 3 to 4 and 3 to 6 days, respectively which is in close agreement with the ongoing discussion (4.40 days) indicating the confirmation of the ongoing discussion.

3.2.7. Sixth instar

The sixth instar larva looked flattened ventrally but appeared convex dorsally. The body looked pale green in colour with two black longitudinal stripes on dorsal side and scattered short hairy setae all over the body. The characteristics of larva during moulting were similar to the preceding instar. Legs were light green in colour.

The body length and breadth of sixth instar larva varied from 25.45 to 30.34 mm (27.71 ± 1.44) and 3.97 to 4.50 mm (4.11 ± 0.13), respectively (Table 1). It was similar to the report of Ali *et al.* (2009) [1] wherein the larval length and breadth was reported in the range of 30.50 to 34.50 and 3.80 to 4.25 mm, respectively when reared on chickpea.

In the present investigation, the duration of sixth instar larva ranged from 4 to 6 days (4.84 ± 0.74) (Table 2). Patel *et al.* (2011) [9] also mentioned it to the tune of 4 to 8 days when reared on rose. The results of this investigation indicated larval duration of 4 to 6 days which is almost the same as reported by the above worker (4 to 8 days).

3.2.8. Total larval duration

The total larval development period of *H. armigera* varied from 20 to 26 days (23.20 ± 1.73). There was hardly any larval mortality observed in the current biological investigation. Ali *et al.* (2009) [1] indicated total larval period of 14 to 20 days on chickpea while Patel *et al.* (2011) [9] reported it to be of 19 to 28 days on rose which is more or less the same as reported in the current investigation (20 to 26 days) indicating the conformity of the findings.

Table 1: Summary of morphometric observations of *H. armigera* when reared on tomato

Sr. No.	Life stages	No. obs.	Size (mm)	Measurement (mm)		Mean \pm S.D.
				Min.	Max.	
1	Egg	25	Length	0.41	0.57	0.49 ± 0.04
			Breadth	0.26	0.89	0.52 ± 0.18
2	Larval instar					
	1 st	25	Length	1.34	1.82	1.56 ± 0.12
			Breadth	0.19	0.36	0.29 ± 0.04
	2 nd	25	Length	3.37	5.96	4.32 ± 0.58
			Breadth	0.63	0.86	0.77 ± 0.06
	3 rd	25	Length	7.13	9.96	8.28 ± 0.69
			Breadth	1.24	1.68	1.40 ± 0.14
	4 th	25	Length	12.38	15.48	13.81 ± 0.89
			Breadth	2.23	2.76	2.44 ± 0.17
	5 th	25	Length	19.38	21.94	20.92 ± 0.58
			Breadth	3.04	3.46	3.24 ± 0.08
	6 th	25	Length	25.45	30.34	27.71 ± 1.44
			Breadth	3.97	4.50	4.11 ± 0.13
	3	Pupa	25	Length	17.23	19.97
Breadth				4.52	5.76	5.14 ± 0.49
4	Adult					
	Male	8	Length	16.20	18.21	17.04 ± 0.74
			Breadth	32.54	34.11	33.06 ± 0.55
	Female	17	Length	18.78	21.45	20.04 ± 0.59
Breadth			33.56	37.23	35.73 ± 0.93	

Table 2: Overall life cycle of *H. armigera*

Sr. No.	Particulars	No. obs.	Period (Days)		Mean \pm S.D.
			Min.	Max.	
1	Incubation period (Days)	25	3	5	3.96 ± 0.73
2	Hatching percentage (%)	4902	2643		53.18
3	Larval period (Days)				
	I instar	25	2	4	2.84 ± 0.74
	II instar	25	3	4	3.40 ± 0.50
	III instar	25	3	5	4.12 ± 0.72
	IV instar	25	3	5	3.60 ± 0.57
	V instar	25	4	5	4.40 ± 0.50
	VI instar	25	4	6	4.84 ± 0.74
	Total larval period (Days)	25	20	26	23.20 ± 1.73
4	Pre-pupal (Days)	25	1	2	1.48 ± 0.50
5	Pupal period (Days)	25	11	15	13.48 ± 1.29
6	Pre-oviposition period (Days)	25	2	3	2.56 ± 0.50
7	Oviposition period (Days)	25	4	7	5.80 ± 0.86

8	Post-oviposition periods (Days)	25	2	3	2.40 ± 0.50
9	Sex ratio (Male: Female)	25	8	17	01: 02.10
10	Adult longevity (Days)				
	Male	8	9	10	9.50 ± 0.53
	Female	17	10	13	11.35 ± 0.86
11	Total life cycle (Days)				
	Male	8	48	56	51 ± 2.97
	Female	17	49	57	53.76 ± 2.43
12	Fecundity	10	408	617	490.20 ± 77.87

3.3. Pre-pupa

Pre-pupal period

The pre-pupal period ranged from 1 to 2 days (1.48 ± 0.50) in the present investigation (Table 2). This stage was reported to last for 1 to 3 days on chickpea (Ali *et al.*, 2009) ^[1] and rose (Patel *et al.*, 2011) ^[9] and 1 to 4 days on groundnut (Gadhiya *et al.*, 2014) ^[4]. The current investigation also indicated pre-pupal period of the pest to the tune of 1 to 2 days which is very close to the above reports (1 to 4 days) thus, conforms the findings.

3.4. Pupa

Length of *H. armigera* pupa varied from 17.23 to 19.97 mm (18.85 ± 0.89), while breadth ranged from 4.52 to 5.76 mm (5.14 ± 0.49) (Table 1). Ali *et al.* (2009) ^[1] revealed length and breadth of pupa as 19.00 and 5.72 mm, respectively on chickpea while, it was 20.93 and 6.09 mm on rose (Patel *et al.*, 2011) ^[9].

The current findings mentioned length and breadth of *H. armigera* pupa as 18.85 and 5.14 mm, respectively is in close agreement to the above reports (19.00-20.93 and 5.72-6.09 mm) thus, conforms the current investigations.

The experimental results indicated pupal period of 11 to 15 days (13.48 ± 1.29) (Table 2). In an earlier study, average pupal period of *H. armigera* was reported to the tune of 13.15 days on chickpea (Ali *et al.*, 2009) ^[1]. The current findings indicated pupal period of 13.48 days which was very close to the above report (13.15 days) indicating conformity of the current investigation.

3.5. Adult

3.5.1. Colour, size, shape and behaviour

The compound eyes of freshly formed adult *H. armigera* moths were dark brown and located laterally on the head. It possessed a pair of setaceous antennae on the dorsal side of the head between the compound eyes. Siphoning type of mouthparts was coiled and rested beneath the head. The adults were of medium size with broad thorax possessing yellowish brown forewings while, legs were long with dirty white showing scaly appearance. There was a distinguished colour pattern between male and female moths. Males were greenish-grey in colour whereas, females were orange brown identified by the presence of tuft of hairs at the tip of abdomen. There was series of the dots on margin and black kidney shaped marking on underside of each forewing. The transparent membranous part of the forewings was covered with creamy coloured scale. Hind wings were lighter in colour and possessed dark coloured patch at the apical end.

The length of adult male varied from 16.20 to 18.21 mm (17.04 ± 0.74) and the breadth varied from 32.54 to 34.11 mm (33.06 ± 0.55). On the other hand, length of the female insect varied from 18.78 to 21.45 mm (20.04 ± 0.59) and the breadth varied from 33.56 to 37.23 mm (35.73 ± 0.93) (Table 1). Pandey and Kumar (2006) ^[8] indicated average length and breadth (with expanded wings) of male *H. armigera* as 16.14

± 0.76 and 30.22 ± 1.28 mm, respectively while, it was 18.65 ± 1.84 and 35.50 ± 1.66 mm, respectively in female insect which confirms that the males were smaller in size than female. Similarly, length and width of male and female insects was reported as 17.65 ± 0.18 and 34.73 ± 0.59 mm and 20.08 ± 0.38 and 40.93 ± 0.55 mm, respectively (Ali *et al.*, 2009) ^[1]. Likewise, length and width of male moth varied from 16.40 to 18.50 and 31.70 to 36.50 mm and 17.90 to 22.50 and 37.60 to 42.10 mm in female, respectively (Gadhiya *et al.*, 2014) ^[4].

In the current investigation, average length and breadth of male and female moths were 17.04 and 33.06 mm and 20.04 and 35.73 mm, respectively which is similar to the above reports thus, the experimental biological findings are said to be in close agreement with the above reports.

3.5.2. Pre-oviposition, oviposition and post-oviposition period

Pre-oviposition period of *H. armigera* varied from 2 to 3 days (2.56 ± 0.50) (Table 2). Patel *et al.* (2011) ^[9] and Gadhiya *et al.*, 2014) ^[4] recorded pre-oviposition period of 2 to 4 days which has been also reported in the current findings (2 to 3 days) thus, confirms the ongoing results.

The oviposition period in the present investigation ranged from 4 to 7 days (5.80 ± 0.86) (Table 2). Oviposition periods of 4 to 7 and 6 to 8 days were reported by Patel *et al.* (2011) ^[9] and Gadhiya *et al.* (2014) ^[4], respectively which were slightly higher than the present investigation (4 to 7 days). Slight variation in the results of the current investigation with those of earlier reports may be due to variation in the laboratory conditions as well as hosts of the current investigation and that of the above workers.

The post-oviposition period during the studies ranged from 2 to 3 days (2.40 ± 0.50) (Table 2). Post-oviposition period of 2.00 ± 0.05 days was observed in the earlier finding (Ali *et al.*, 2009) ^[1]. Earlier reports of Patel *et al.* (2011) ^[9] and Gadhiya *et al.* (2014) ^[4] also indicated 0 to 2 days of post-oviposition period. In the current investigation, post-oviposition period of 2 to 3 days is nearly the same (0 to 2 days) as reported in the above reports thus, confirms the ongoing findings.

3.5.3. Fecundity

The egg laying capacity of female *H. armigera* moths varied from 408 to 617 eggs (490.20 ± 77.87) per female on tomato under laboratory condition (Table 2). Almost similar fecundity (290 to 910 eggs/female) of *H. armigera* was observed on rose by Patel *et al.* (2011) ^[9], chickpea by Ali *et al.* (2009) ^[1] and on groundnut by Gadhiya *et al.* (2014) ^[4] which were in the range of 290 to 910, 405 to 420 and 163 to 318 eggs per female, respectively. The results of 408 to 617 eggs per female obtained in the current investigation looked nearly similar to the reports of Ali *et al.* (2009) ^[1] on chickpea (405 to 420 eggs/female) thus conforms the current findings whereas, it differed from other reports of Patel *et al.* (2011) ^[9]

and Gadhiya *et al.*, (2014) ^[4] which could be due to variation in the hosts used in and the laboratory conditions.

3.5.4. Hatching percentage

Out of 4902 eggs observed under laboratory conditions, 2643 eggs hatched indicated hatching of 53.18 per cent when reared on tomato (Table 2). In an earlier report (Gadhiya *et al.*, 2014) ^[4] hatching of 59 per cent was observed on groundnut which is nearly the same (53.18%) as mentioned by Gadhiya *et al.* (2014) ^[4] thus confirms the current investigation.

3.5.5. Adult longevity

The longevity of adult male ranged from 9 to 10 days (9.50 ± 0.53) while mated female lived for 10 to 13 days (11.35 ± 0.86) (Table 2). According to Ali *et al.* (2009) ^[11], both male and female *H. armigera* lived for about 7 to 11 and 10 to 14 days, respectively. Similarly, Patel *et al.* (2011) ^[9] recorded longevity of male and female adults as 4 to 8 and 5 to 11 days, respectively while, Gadhiya *et al.* (2014) ^[4] reported duration of male and female adults as 7 to 8 and 8 to 10 days, respectively. The results of the above workers look similar to the findings obtained in the current investigation (9 to 10 and 10 to 13 days, respectively) on the basis of duration. This has also proved that adult male lived for a shorter period as compared to the female insect.

3.5.6. Sex ratio

Based on morphological characters (female insect had tuft of hairs at the tip of the abdomen), the adults were differentiated into sexes. Out of 25 adults emerged from laboratory mass culture during the investigation, 8 were males and 17 were females, which indicated the preponderance of female. The sex ratio of male to female was 1: 2.10 (Table 2). Pandey and Kumar (2006) ^[8] found the sex ratio of male: female to the tune of 1:0.76 while, it was 1:0.72 recorded by Patel *et al.* (2011) ^[9]. On the other hand, it was 1: 1.08 in laboratory and 1:1.15 in field condition mentioned by Ghadiya *et al.* (2014) ^[4]. In the current investigation, male to female sex ratio was 1:2.10 which looks slightly higher than the earlier reports (1: 0.72 - 0.78). The variation in the sex ratio may be because of different hosts used in these investigations.

3.6. Total life cycle

The total life span from egg to the death of adult occupied by male was 48 to 56 days (51 ± 2.97) while, female occupied 49 to 57 days (53.76 ± 2.43) (Table 2). Thus, total life period of male was shorter than female during the present investigation. Pandey and Kumar (2006) ^[8] reported entire life span of *H. armigera* from egg to death of adult male as 52.8 ± 3.56 days whereas, in female, it was 58.6 ± 4.52 days. The results of the current investigation indicated total life cycle of male and female insect was to the tune of 51 and 53.76 days, respectively which is almost the same (52.8 and 58.6 days, respectively) as indicated by Pandey and Kumar (2006) ^[8]. Thus, it can be concluded that the adult insect survived for shorter period as compared to the female insect which is also observed in the earlier report and the current investigation.

4. Conclusion

Biological studies of *Helicoverpa armigera* on tomato revealed hemispherical shaped and yellowish white insect eggs wherein incubation period ranged from 3 to 5 days while, hatchability was 53.18 per cent. The neonate larva was dirty white which at full maturity turned to pinkish brown and

pale green. The larvae passed through six instars wherein their respective durations were of 2.84, 3.40, 4.12, 3.60, 4.40 and 4.84 days. All the larval instars consumed 23.20 days. The pupal period was of 13.48 days. Male and female moths looked greenish-grey and orange brown, respectively. Pupa was characterized by tuft of hairs at the tip of abdomen. The sex ratio (Male: female) was 1:2.10. The pre, oviposition and post- oviposition periods were of 2.56, 5.80 and 2.40 days, respectively. The fecundity was 490.20 eggs per female. Adult male and female longevities were of 9.50 and 11.35 days, respectively. Total life cycle of male and female insects was completed in 51 and 53.76 days, respectively indicating higher adult longevity in female insect than male.

5. References

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