Standardization of artificial diet for the mass rearing of *Helicoverpa armigera*

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Abstract

Experiment was carried out to standardize the artificial diet for mass rearing of Helicoverpa armigera *(Hübner) under laboratory conditions. The average length and breadth of egg was 0.51±0.06 mm, 0.46±0.37 mm and 0.52±0.03 mm, 0.48±0.62 on artificial and natural diet. The average length and breadth of first, second, third, fourth and fifth instar larvae was 1.40±0.09 mm, 0.46±0.02 mm and 1.42±0.01 mm, 0.47±0.16 mm and 4.03±0.22 mm, 0.66±0.07 mm and 4.31±0.01 mm, 0.89±0.25 mm and 8.19±0.36 mm, 1.57±0.63 mm, and 10.29±0.72 mm, 1.87±0.91 mm and 18.70±0.44 mm, 2.78±0.040 mm and 20.15±0.03 mm, 3.17±0.55 mm and 26.01±0.19 mm, 4.09±0.39 mm and 27.32±0.027 mm, 5.88±0.69 mm, respectively with the average duration of 2.69±0.32 and 2.54±0.29, 3.77±0.65 and 3.79±0.11, 3.88±0.49 and 3.72±1.23, 5.35±0.55 and 5.72±0.91 and 6.61±0.008, 6.46±1.07 days, respectively on artificial as well as on natural diet. The average length and breadth of adult male and female was 18.01±0.48 mm and 35.09±1.25 mm, 18.51±1.04 mm and 38.11±1.37 mm, 19.00±0.18 mm and 19.10±0.49 mm, 37.75±1.27 mm and 41.23±1.69 mm, respectively. The average pre-oviposition, oviposition and post-oviposition period was 2.52±0.86 and 2.76±0.84 days, 4.93±0.78 and 5.08±0.90 days and 0.65±0.49 and 0.79±0.93 days, respectively. The total life cycle of male and female was 40.50±2.29 and 41.81±1.89 days and 42.59±1.77 and 43.80±1.93 days.*

Keywords: Artificial diet, *Helicoverpa armigera,* mass rearing, standardization.

Introduction

Helicoverpa armigera (Hübner) known as legume pod borer, is a polyphagous in nature, having wide geographic distribution and causes havoc damage in major cultivated as well as in wild plants as a key pest (Sigsgaard *et al*., 2002; Singh and Yadav, 2009 and Choudhury *et al*., 2013; Feng *et al*., 2005). In India it is reported on 60 cultivated and 67 wild plants (Karim, 2000).

To study the different biological parameters, feeding habits and their susceptibility and resistance to pesticides, it is necessary to rear all the economically important insects (Abbasi *et al*., 2007). Bioassay and toxicological studies like determination of LC_{50} values, concentration-probit curve, residual toxicity and resistance studies are important techniques, which is being performed in the controlled conditions for evaluations against this pest. For all the studies, the availability of this pest year around is quite difficult.

To meet the demand of laboratory reared insects, low cost artificial diets are required that could improve their development (Nagarkatti and Prakash, 1974; Armes *et al*., 1992; Singh and Rembold, 1992; Wu and Gong, 1997 and Ahmed *et al*., 1998). However, few success efforts have been reported (Coudron *et al*., 2005) to rear successive generations of economically important insects entirely on an artificial diet but there are chances of loss of fitness and reproductive potential which cause longer development times and lower fecundity (Cohen, 2003).

Due to its high fecundity, polyphagous nature and quick adaptation against insecticides, control with any single potent toxicant for a long time is quiet difficult and rather impossible due to development of cross-resistance to many popular insecticides. This has promoted the necessity for the development of new, safer, biodegradable insecticides and known insecticidal alternatives that could be feasible and effective for management of this pest. Indiscriminate use of chemical pesticides has led to triggering of resistance development, environmental pollution and residual hazards to ecosystem (Gowda 2005). Successful management of *Helicoverpa armigera* requires the integration of several control tactics. In absence of natural food, this insect reared on artificial diets to know its biological parameters, which are helpful in determining their susceptible stage to the insecticides. For toxicological studies like determination of LC_{50} values, concentration-

probit curve, residual toxicity and resistance studies, mass rearing of this pest on artificial diet plays an important role. Rearing of *Helicoverpa armigera*, on artificial diet beyond its natural habitat is a big challenge to maintain its genetic vigor without any genetic drift generation after generation judge our physical potential and knowledge as well. Therefore, the present study was carried out to evaluate the performance of simple low cost artificial diet for mass rearing of *Helicoverpa armigera* under controlled laboratory conditions and from which different instars of larvae were taken for different bioassay and concentration-probit mortality curve investigations.

Materials and methods

To evaluate the performance of artificial diet for the mass rearing of *H. armigera*, *e*xperimental trial was carried out at Pesticide Resistance Management Laboratory, Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana (India).

Rearing material

For rearing of the test insect, materials *viz*., battery glass jars (20 cm x 15 cm diameter), hexagonal plastic tissue culture plates, glass petri dishes (1.5 cm x 10 cm diameter), glass petri dishes (2.5 cm x 20 cm diameter), muslin cloth, cotton, rubber bands, camel hair brush grinder and mixture, wooden wired incubation chamber, hatching trays, glass conical flask for reparation of 10 per cent honey solution, water distillation unit, sterilization unit for sterilize the plastic, glass materials and other rearing materials etc.

Ingredients for preparation of artificial diet

Kabuli gram seed (Bold seed 105 g), Agar-agar powder (12.75 g), Yeast extract powder (10 g), Ascorbic acid extra pure (3.75 g), Sorbic acid (1 g), Methyl-4-hydroxybenzoate (2 g), Streptomycin sulphate (0.25 g), Multivitamin multi-mineral capsules (200 mg – 2 Nos.), Vitamin E capsule (200 mg – 2 Nos.), 10 per cent formaldehyde solution 37-41% w/v LR (2 ml), ground nut seeds (4 – 5 seeds per diet), distilled water (780 ml), and electronic digital weighing balance.

Procedure for preparation of artificial diet

Take 105 g sterilized Kabuli gram seeds in a grinder along with 4-5 ground nut seeds and grind the material until the material become a rough flour. Grind flour along with yeast extract powder, methyl-4-hydroxybenzoate and ascorbic acid and distilled water in a prescribed quantity put into a blender for mixing and mixture was run for 2-3 minutes. In another container 12.75 g agar- agar powder was boiled in 390 ml distilled water for 2-3 minutes and put it on room temperature for cooling. The dissolved agar-agar solution was then poured in blender and blended for 10 to 15 seconds. The remaining ingredients *viz*., multivitamin multi-mineral capsules, vitamin E capsules, sorbic acid, streptomycin sulphate and formaldehyde solution 10 per cent were then added to the blended material. The capsules were cut at one side with the help of scissor and pressed them to come out the inner material. The vitamins and protein were added in semi cool mixture, because in warm mixture, vitamins and proteins get clotting, hence to avoid this, the agar-agar solution was cooled at room temperature before putting in mixture. The mixture was again run for one minute for complete mixing. The mixture was poured in sterilized glass petri dishes (2.5 cm x 20 cm diameter) up to half 1.5 cm height. These petri dishes were kept at cooler location for solidifying the diet and after half an hour the it is ready to feed to the test insect.

Test insect

Large number of larvae were collected from the pigeonpea field and rearing of this pest was maintained on artificial diet at controlled conditions (26±1 ºC temperature and 75% relative humidity) for consecutive two years during summer and winter season. The fresh artificial diet was provided daily on the consumption requirement of the larvae. When larvae turn into pupae, they were separated in to glass battery jars (20 cm X 15 cm diameter) containing moist sand. After 10 to 15 days adults emerge out from the pupation and adults were then transferred to other glass jars containing paper towels at bottom to reduce excess moisture, muslin cloth, and rubber bands on the mouth of the glass jars to cover the mouth of glass jars. The adult population in the glass jars was maintained at 50-50 per cent male and female ratio. Ten per cent honey solution in cotton swab was also provided for adult food daily. After 3-4 days female starts egg laying on the muslin cloth. Muslin cloth containing eggs removed from the glass jars and replaced it 3-4 times with a new muslin cloth until total oviposition is realized. Egg laid on muslin cloths were kept in incubation chamber for hatching within 2 to 3 days. Newly hatched neonate larvae were removed from the muslin cloth with the help of wet camel hair brush without inflicting any damage and transferred them in to small petri dishes (1.5 cm x 10 cm diameter) containing a small piece of artificial diet. Second instar larvae were kept separate into hexagonal plastic tissue culture plates and provide fresh food daily. To avoid any fungal or bacterial contamination due to their excreta, on every next day the larvae were transferred in to a new hexagonal plastic culture plates along with new diet. The old ones were sent

for cleaning and sterilization for their use on next turn. Rearing laboratory was disinfected regularly at weekly interval to inhibit the growth or action of microorganism by using sodium hypochlorite.

Results and discussion

The eggs laid on the muslin cloth were placed in another container in incubation chamber for hatching. After hatching, the neonate larva were removed with the help of wet camel hair brush to study morphometrics and various developmental stages.

Morphometrics of different developmental stages of *H. armigera*

Eggs

Female laid single hemispherical round shaped eggs in yellowish-white color and the color changed into dark brown at hatching. The morphometrics of different stages of *H. armigera* (Table 2) showed that the average length and breadth of eggs on artificial diet was 0.51±0.06 mm and 0.46±0.37 mm respectively whereas, the same 0.52±0.03 mm and 0.48±0.62 mm was on natural diet. More or less similar observations were reported by Gadhiya *et al*., (2014), according to them length and breadth of eggs were 0.47±0.02 mm and 0.49±0.02 mm, respectively. Baikar and Naik (2016) measured 0.41 mm to 0.62 mm of egg length with an average of 0.51±0.07 mm and 0.38 mm to 0.56 mm in breadth with an average of 0.46±0.062 mm. Patil *et al*., (2018) also reported that the length and breadth of freshly laid eggs was 0.49±0.04 mm and 0.51±0.04 mm, respectively.

Larval instars

Five instars were found on artificial as well as on natural diet and the average length of first instar was 1.40±0.09 mm and average breadth was 0.46±0.02 mm on artificial diet. On natural diet, the average length and breadth of first instar larva was 1.42±0.01 mm and 0.47±0.16 mm, respectively. Second instar larva having 4.03±0.22 mm, 0.66±0.07 and 4.31±0.01, 0.89±0.25 mm length and breadth respectively on artificial as well as on natural diet. Likewise, for the third instar larva, the average length and breadth was recorded of 8.19±0.36 mm and 1.57±0.63 mm, respectively on artificial diet, whereas, the same was 10.29±0.72 mm and 1.87±0.91 mm on natural diet. The average length and breadth of fourth instar larva on artificial diet was 18.70±0.44 mm and 2.78±0.040 mm. On natural diet, it was 20.15±0.03 mm and 3.17±0.55 mm, respectively. At full maturity of the fifth larval instar on natural diet, the average length and breadth was 26.01±0.19 mm, 4.09±0.39 mm and 27.32±0.027 mm and 5.88±0.69 mm, respectively. According to Gadhiya *et al*., (2014), the average length of first, second, third, fourth and fifth instar larvae was 1.80±0.11, 4.69±0.38, 8.46±0.47, 17.60±0.83 and 28.76±1.05 mm, respectively. The average breadth of the same was 0.31±0.02, 0.62±0.04, 1.01±0.17, 2.21±0.15, and 3.68±0.33 mm, respectively. The results are in agreement with the findings of Parmar (2006), who reported length and breadth of respective larvae were 1.74±0.12 and 0.30±0.01, 4.85±0.42 and 0.49±0.02, 8.46±0.47 and 1.01±0.17, 17.42±0.75 and 0.49±0.02, 8.46±0.47 and 1.01±0.17, 17.42±0.75 and 2.21±0.10, 28.76±1.05 and 3.56±0.14 mm, respectively.

Pre-pupa

The average length and breadth of pre-pupal stage on artificial as well as on natural diet was 22.18±0.51 mm, 3.79±1.56 mm and 24.44±1.13 mm and 5.03±0.08 mm, respectively.

Pupa

The average length and breadth of male pupal (Table 3) stage on artificial as well as on natural diet was 18.82±1.19 mm, 3.58±1.29 mm and 20.33±0.05 mm and 4.79±1.63 mm, respectively. Whereas, in female pupa the average length and breadth was 19.23±1.58 and 4.86±1.22 mm and 19.41±1.33 and 4.94±1.50 mm, respectively on artificial as well as on natural diet. The distance between genital pore and anal pore was 0.64±0.04 and 0.65±0.01 mm in case of male pupa, while in case of female pupa, the distance between the same was 1.66±0.06 and 1.72±0.05 mm, respectively. More or less similar observations were recorded by Patil *et al*., (2018), according to them the distance between anal and genital pores of male pupa was 0.56±0.45 mm, while in female, it was 1.55±0.11 mm. Gadhiya *et al*., (2014) reported 21.09±1.12, 5.54±0.46 mm and 0.60±0.02 length, breadth and distance between genital and anal pore in case of male pupa. Whereas, in female pupa it was 21.37±1.74, 5.80±0.49 mm and 1.74±0.04 mm, respectively.

Adult male

The average length and breadth of adult male on artificial as well as on natural diet was 18.01±0.48 mm, 35.09±1.25 mm and 18.51±1.04 mm and 38.11±1.37 mm, respectively. The results are in close confirmation with the findings of Gadhiya *et al*., (2014), according to them the length and breadth of adult male moth was 17.55±0.52 mm and 34.62±1.49 mm. Parmar (2006) also stated that the length of male moth was ranged from 16.50 to 19.00 mm with an average of 17.70±1.03 mm. similarly Patil *et al*., (2018) reported the length of adult male varied from

Table 1. Ingredients used for preparation of artificial diet

Ingredients	Quantity (g/ml/mg) for one diet
Kabuli gram flour	105 g
Methyl Para-hydroxy benzoate	2 g
Baker's yeast	10 g
Ascorbic acid	3.75 g
Agar-agar	12.75 g
Sorbic acid	1 g
Streptomycin sulphate	0.25 g
Multivitamin capsule (250 mg)	2 Nos.
Vitamin capsule (250 mg)	2 Nos.
Formalin 10 per cent solution	2 ml
Groundnut oil or groundnut seed	1-2 drops or 8 -10 seeds
Distilled water	780 ml

15.94 to 18.21 mm with an average of 16.94±0.83 mm and the breadth varied from 32.18 to 34.79 with an average of 33.12±0.82 mm, respectively.

Adult female

The length of the female moth on artificial as well as on natural diet was 19.00±0.18 mm and 19.10±0.49 mm, respectively. Whereas, the average breadth of female moth (wing expansion) was 37.75±1.27 mm and 41.23±1.69 mm on artificial as well as on natural diet, respectively. More or less observations was also noted by Thakor *et al*., (2009), according to them length and breadth of female moth was 19.30±0.79 mm and 39.01±1.64 mm, respectively. Gadhiya *et al*., (2014) also reported similar results, according to them length and breadth of adult female moth was 21.09±1.28 mm and 40.77±1.68 mm, respectively. According to Parmar (2006) female moth breadth with expanded wings varied from 32.00 to 37.00 mm with an average of 34.20±1.92 mm, while, the length of female moth was ranged from 18.00 to 22.50 mm with an average of 20.10±1.74 mm.

Duration of different developmental stages of *H. armigera*

Incubation period

The developmental stages of *H. armigera* presented in Table 3. The incubation period was 3.35±1.18 and 3.78±0.45 days on artificial and natural diet respectively. Present findings are in line with the findings of Herald and Tayde (2018), according to them in the laboratory studies the incubation period of eggs was 3.50±0.52 days. The results are in confirmation with the findings of Gadhiya *et al*., (2014), according to them, the incubation period of egg under laboratory conditions was 2 to 4 days. Similarly, the incubation period of egg was also reported 2 to 5 days in laboratory conditions by Patil *et al*., (2018).

Larval instars

Five larval instars of *H. armigera* were observed (Table 3) on artificial and natural diet, respectively.

Table 2. Morphometrics of different developmental stages of H. armigera on artificial and natural diet

Stage		Measurements on artificial diet		Measurements on natural diet	
		Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
		Mean ± S.D.		Mean ± S.D.	
	Egg	0.51±0.06	0.46±0.37	0.52±0.03	0.48±0.62
Larval instar	**1st**	1.40±0.09	0.46±0.02	1.42±0.01	0.47±0.16
	2nd	4.03±0.22	0.66±0.07	4.31±0.01	0.89±0.25
	3rd	8.19±0.36	1.57±0.63	10.29±0.72	1.87±0.91
	4th	18.70±0.44	2.78±0.040	20.15±0.03	3.17±0.55
	5th	26.01±0.19	4.09±0.39	27.32±0.027	5.88±0.69
	Pre-pupa	22.18±0.51	3.79±1.56	24.44±1.13	5.03±0.08
Pupa	Male	18.82±1.19	3.58±1.29	20.33±0.05	4.79±1.63
	Genital & anal pore distance	0.64±0.04		0.65±0.01	
	Female	19.23±1.58	4.86±1.22	19.41±1.33	4.94±1.50
	Genital & anal pore distance	1.66±0.06		1.72±0.05	
Adult	**Male**	18.01±0.48	35.09±1.25	18.51±1.04	38.11±1.37
	Female	19.00±0.18	37.75±1.27	19.10±0.49	41.23±1.69

Table 3. Duration of various developmental stages of H. armigera on artificial and natural diet (in days)

Particulars Mean ± S.D.		Artificial diet	Natural diet
		Mean ± S.D.	
Incubation period		3.35±1.18	3.78±0.45
Larval period	1st	2.69±0.32	2.54±0.29
	2nd	3.77±0.65	3.79±0.11
	3rd	3.88±0.49	3.72±1.23
	4th	5.35±0.55	5.72±0.91
	5th	6.61±0.008	6.46±1.07
Total larval period		22.32±1.27	22.69±1.60
Pre-pupal		2.31±0.04	2.34±0.51
Pupal		9.79±1.00	10.04±1.06
Adult longevity	Male	5.11±0.08	5.46±0.33
	Female	7.71±1.16	8.15±1.04
Pre-oviposition		2.52±0.86	2.76±0.84
Oviposition		4.93±0.78	5.08±0.90
Post-oviposition		0.65±0.49	0.79±0.93
Total life cycle	Male	40.50±2.29	41.81±1.89
	Female	42.59±1.77	43.80±1.93
Fecundity		509.34±245.09	569.05±201.48
Egg hatchability (%)		87.03±7.55	88.17±7.66

1st instar larva

The first instar larva was creamy white in color and semi-translucent with yellowish to dark brown head capsule. The average duration of 1st instar larva was 2.69±0.32 and 2.54±0.29 days, respectively on artificial as well as on natural diet. According to Gadhiya *et al*., (2014), the average duration of first larval instar was 2.84±0.37 days. Similarly, Patil *et al*., (2018) and Baikar and Naik (2016) noted average larval duration of first instar larvae was 2.88±0.73 and 2.4±0.52 days, respectively under laboratory conditions.

2nd instar larva

As of first instar larva, second instar larva was also morphologically resembled in body color but with slightly more activeness. The average duration of 2nd instar larva was 3.77±0.65 and 3.79±0.11 days, respectively on artificial as well as on natural diet. According to Gadhiya *et al*., (2014), the average duration of second larval instar was 2.80±0.76 days. However, under laboratory conditions the average second instar larval period was 2.7±0.48 days on chilli (Bailar and Naik, 2016).

3rd instar larva

As compared to 2nd instar larva, little changes in 3rd instar larva were observed in the size and shape. The body color was brown to yellowish with clear lateral diamond shaped rings and longitudinal lines on both the sides. The average duration of 3rd instar larva was 3.88±0.49 and 3.72±1.23 days, respectively on artificial as well as on natural diet. Present findings are supported by the observations taken by Baikar and Naik (2016) and Herald and Tayde (2018), they reported 3.8±0.42 and 3.60±0.51 days duration of third instar larva under laboratory conditions on chilli and tomato crop. Results are differed from the findings of Gadhiya *et al*., (2014), the average duration of third larval instar was 4.16±0.69 days.

4th instar larva

Color, shape, and size variations was clearly different in 4th instar larva as compared to 3rd instar larva. Larval body was with black spots and brownish to greenish in color. Yellowish lateral lines on each side was also clearly visible. Remarkably larger size of 4th instar larva was observed. On artificial as well as natural diet, the duration of 4th instar larva was increased by 2 days in comparison to 3rd instar larva. The duration of 4th instar larva was 5.35±0.55 and 5.72±0.91 days, respectively on both the diets. According to Gadhiya *et al*., (2014), the average duration of fourth larval instar was 5.20±0.87 days. However, the larval duration of fourth instar was 4.40±0.52 days under laboratory conditions on tomato crop (Herald and Tayde, 2018). Baikar and Naik (2016) also reported 4.3±0.48 days duration of larval instar on chilli under laboratory conditions. Results were contradicted by Patil *et al*., (2018), according to them the average larval duration of fourth instar larvae was 3.73±0.70 days on chilli fruits.

5th instar larva

The 5th instar larva was brown pinkish to greenish in color. Dorsal strips are clearly visible and black spots are slightly dissolve in the body color or less in numbers. The average duration of fifth instar larva was 6.61±0.008 and 6.46±1.07 days, respectively on artificial as well as on natural diet. Results are different from the findings of Gadhiya *et al*., (2014), according to them, the average duration of fifth larval instar was 5.44±0.96 days on groundnut crop under field conditions. Results are totally differed from Baikar and Naik (2016), they reported 4.5±0.53 days duration of fifth larval instar on chilli under laboratory conditions. Herald and Tayde (2018) also reported that the average duration of fifth larval instar was 4.70±0.48 days.

Total larval period

The total larval period was 22.32±1.27 and 22.69±1.60 days, respectively (Table 3) on artificial as well as on natural diet. The results are in confirmity with the findings of Gadhiya *et al*., (2014) and Baikar and Naik (2016), according to them the total larval period varied from 15 to 26 days with an average of 22.44±2.75 and 21.8±0.79 days, respectively under field conditions on groundnut and laboratory conditions on chilli. The findings on larval period also corroborates with the findings of Dubey *et al*., (1981), they reported 18 and 20 days larval period on chickpea and pigeonpea crop, respectively.

Pre-pupal and pupal period

The average pre-pupal and pupal period was varied from 2.31±0.04, 2.34±0.51 days and 9.79±1.00 and 10.04±1.06 days on artificial as well as on natural diet. Results are in accordance with the findings of Herald and Tayde (2018), according to them the pre pupal and pupal period was 2.10±0.73 and 13.80±0.91 days, respectively. Patil *et al*., (2018) also reported that the pupal period varied from 11 to 15 days with an average of 12.67±1.28 days. However, the results are differed from the findings of Gadhiya *et al*., (2014), they reported that the duration of male pupae varied from 15 to 18 days with an average of 16.60±1.12 days, while, duration of female pupae varied from 14 to 20 days with an average of 17.36±1.75 days, respectively.

Adult longevity

Longevity of male and female moths were 5.11±0.08, 5.46±0.33 days and 7.71±1.16, 8.15±1.04 days, respectively on artificial as well as on natural diet. Results showed that female moth live longer than the male moth. More or less similar observations were reported by Gadhiya *et al*., (2014), according to them the longevity of male and female moth was 7.64±0.49 and 9.08±0.70 days, respectively on groundnut crop. Patil *et al*., (2018) also reported that the longevity of male was ranged from 7 to 10 days with an average of 8.67±1.06 days, whereas, mated female moth lived for 9 to 13 days with an average of 10.90±1.22 days, respectively. Similarly, Herald and Tayde (2018) observed that longevity of adult ranged from 8 to 10 days with an average of 8.90±0.87 days in male, while the longevity of female moths ranged from 10 to 14 days with an average of 11.90±1.44 days.

Pre-oviposition, oviposition, and post-oviposition period

Results presented in Table 3 revealed that the average pre-oviposition period was 2.52±0.86 and 2.76±0.84 days, respectively on artificial and natural diet. The average oviposition period was 4.93±0.78 and 5.08±0.90 days, whereas, the average post-oviposition period was 0.65±0.49 and 0.79±0.93 days, respectively. The present findings are in accordance with the observations of Herald and Tayde (2018), they reported that the mean pre-oviposition, oviposition and post-oviposition period on tomato crop was 2.90±0.73 days, 5.50±0.52 and 1.60±0.51 days, respectively. The observations more or less in confirmity with the findings of Bhatt and Patel (2001), who reported that the pre-oviposition, oviposition and post-oviposition period was 2.85, 7.5 and 1.10 days, respectively on chickpea plant. Gadhiya *et al*., (2014) also reported pre-oviposition, oviposition and post-oviposition was 2 to 4, 6 to 8 and 0 to 2 days with an average duration of 2.60±0.76, 7.04±0.61 and 1.08±0.70 days, respectively

on groundnut crop.

Total life cycle

The total life cycle of male *H. armigera* was 40.50±2.29 and 41.81±1.89 days, while in case of female moth, it was 42.59±1.77 and 43.80±1.93 days, respectively on both the diets. Results are contradictory with the findings of Gadhiya *et al*., (2014), according to them, the total life cycle of *H. armigera* was occupied on an average of 49.40±5.21 days ranging from 40 to 61 days in case of male, while 52.40±7.03 days ranging from 43 to 65 days in case of female moth. Thakor *et al*., (2009) also reported that total life cycle of *H. armigera* was ranged from 46 to 49 days with an average of 47.40±0.84 days in case of male and 46 to 52 days with an average of 50.00±2.26 days in case of female moth.

Fecundity per female

The fecundity of female moth on artificial as well as on natural diet was 509.34±245.09 and 569.05±201.48 per female, respectively. Results are in close agreement with the findings of Herald and Tayde (2018), the fecundity of *H. armigera* was 260 to 495 eggs with an average of 381.4±86.88. The observations are also in accordance with Sharma *et al*., (2011), who reported that the female of *H. armigera* laid 256.60 to 490.66 eggs. The results are not supported by Gadhiya *et al*., (2014), according to him the egg laying capacity of female moth was varied from 163 to 318 eggs with an average of 255.88±43.21 eggs. More fecundity of 1048.40±193.58 eggs with an average of 742 to 1235 eggs by female moth was recorded by Patil *et al*. (2018) under laboratory conditions on chilli.

Per cent egg hatchability

Hatching percentage of eggs was 87.03±7.55 and 88.17±7.66 per cent (Table 3) on artificial as well as on natural diet. Present findings are in line with observation of Parmar (2006), Patel *et al*. (2011) and Sharma *et al*. (2011), who stated that hatching per cent of *H. armigera* eggs was ranged from 55 to 85% on chickpea and 57 to 89% on okra, 83% on rose and 89% on tomato, respectively. According to Patil *et al*., (2018), out of 10484 eggs, 5577 eggs hatched with the hatchability of 53.20% when larvae reared on chilli under laboratory conditions.

The present studies are concluded and presented in the accompanying lines. The developmental studies of *H. armigera* provides detailed information on biological parameters, feeding habits and susceptibility and resistance of stages to pesticides through which, bioassay aspects can be studied on the vulnerable stages of the target insect. Rearing of *H. armigera* under laboratory conditions on artificial diet with the minimum genetic drift is a big challenge. This can be achieved only by standardizing an easy and effective mass rearing method. We reared the *H. armigera* culture continue for two years using this method without a big genetic drift. Long time availability of the respective insect's culture keeps research activities in full swing *viz*., on taxonomy, systematics, bioassay and toxicological studies like determination of LC_{50} values, concentration-probit curve, residual toxicity, resistance, and physiological studies etc. which are being performed in the controlled conditions for evaluations against target insect.

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