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Comparative biology of *Helicoverpa armigera* (HUBNER) reared on tomato during different seasons

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Abstract
In present study, experiments on comparative biology of *Helicoverpa armigera* Hübner were conducted during pre *Rabi, Rabi* and post *Rabi* seasons. Results showed that post *Rabi* season was most preferred where maximum length and breadth of eggs, larval instars, pre pupa, pupa and, adult male and female with minimum hatching period of eggs, duration of larval instars, pre pupa, pupa, adult longevity of *H. armigera*, were recorded. *Rabi* season was least preferred with minimum length and breadth and maximum duration of the eggs, larval instars, pre pupa, pupa and, adult male and female development. The pre-oviposition, oviposition and post-oviposition periods and mean fecundity were also recorded maximum during post *Rabi* season. and minimum during *Rabi* season. With maximum growth index (4.03), post *Rabi* season was most congenial period for the development, while *Rabi* season was least with minimum growth index (2.59).

Keywords: Helicoverpa armigera, biology, tomato, pre Rabi, Rabi, post Rabi seasons

1. Introduction
Tomato (*Lycopersicon esculentum* Mill.) is an important profitable crop and gives higher yield to the growers [1]. Due to its relative short duration, tomato crop has become economically attractive to the farmers and the area under cultivation is increasing day by day around the world [2]. However, all the stages of tomato crop right from nursery to maturity are attacked by a large spectrum of insect pests. Among these insect pests of tomato, fruit borer, *H. armigera* is very important which causes 40-50 per cent damage to the crop [3]. *H. armigera* is a charismatic insect pest in agriculture accounting for the consumption of over 55 per cent of total insecticides used in India [4]. The problem of pest is magnified due to its direct attack on fruiting structures, voracious feeding habits, high mobility, fecundity and multivoltine overlapping generations [5]. 1999). Besides, the outbreak of *H. armigera* on crops has been attributed to the development of insecticide resistance to broad spectrum of insecticides used in the agriculture and are known to have detrimental effect on the populations of its natural enemies [6]. Exposure of successive generations while moving from one crop to another, has made this pest highly resistant to the pesticides i.e. cyclodiene, pyrethroids, organophosphates, carbamates etc. [7]. *H. armigera* has become threat to the intensive agriculture. To develop efficient pest management strategies, a thorough knowledge on the biology of this pest and its status during different times provides an important basis. Therefore, the present investigation was undertaken to study the comparative biology of *H. armigera* on tomato during different seasons under laboratory conditions.

2. Materials and Methods
The studies on comparative biology of *H. armigera* on tomato in three different seasons *viz.,* pre *Rabi* (first week of October to last week of November), *Rabi* (first week of December to second week of February) and post *Rabi* (first week of March to last week of April) of 2013-14 were carried out in the laboratory of Department of Entomology, C.P. College of Agriculture, S.D.A.U., S. K. Nagar. During the experimentation the temperature and relative humidity were recorded in pre *Rabi* as 25.40 ± 2.95 ^{0}C and 59.10 ± 7.30 per cent, in *Rabi* as 20.73 ± 2.55 ^{0}C and 65.77 ± 7.65 percent and in post *Rabi* as 27.57 ± 3.48 ^{0}C and 53.00 ± 6.46 per cent, respectively.

2.1 Rearing of *H. armigera*

Fruit borer, *H. armigera* larvae were collected from the unsprayed tomato field of Horticulture Instructional farm, C.P.C.A, SDAU, Sardarkrushinagar. The collected larvae were reared in the laboratory on leaves and fruits of tomato. The larvae were kept individually in plastic tubes (3.8 cm diameter x 5 cm height) closed with lid to avoid cannibalism. Tomato leaves, fruits and plastic tubes were changed daily to maintain sanitation. The larvae pupated in the tubes were taken out and kept in Petri dish in separate rearing cages (30 cm x 30 cm x 30 cm) for emergence of adults. Male and female adults emerging out were collected and paired for mating. The tomato plant with young leaves and fruits were placed inside the cage for egg laying. Absorbent cotton dipped in 5 per cent honey solution was served as food for the adults. The freshly laid eggs on leaves and fruits were used for further studies.

2.2 Larva

To determine the number and duration of different larval instars and total larval period, the larvae were reared in separate plastic tubes by providing tender and fresh leaves or fruits as the food. The food and plastic tubes were changed daily in the morning. The molting was confirmed by casted off exuvia and increased size of larvae of subsequent instars. The larvae in each instar were studied for their colour, shape and size. The length and breadth of all larval instars were measured with the help of stage and ocular micrometer. Observations on number of instars, duration of each instar and total larval period were recorded separately. The total larval duration was calculated from the date of hatching of egg to the end of final instar.

2.3 Pre-pupa

When full grown larvae ceased feeding, turned darker, wrinkled and sluggish, it was considered as pre-pupal stage. The length and breadth of all the pre-pupae formed were measured by using stage and ocular micrometer. The period between formation of pre-pupa and pupa was taken as pre-pupal period and recorded.

2.4 Pupa

The individual pupa was examined for their morphological characters, colour and size. The length and breadth of the pupae were also measured by using stage and ocular micrometer. The male and female sex was determined by examining the distance between the genital slit and anal slit of the pupa. Pupal period was calculated from the date of formation of pupa to the date of emergence of adult from the pupa.

2.5 Growth Index

The growth index value was worked out by using the following formula [8].

$$\text{Growth index} = \frac{\text{Larval survival (\%)}}{\text{Average duration of larval period}}$$

2.6 Sex ratio

The sex ratio determined in the pupal stage based on distance between genital slit and anal slit in male and female pupae.

2.7 Adult

The male and female adults from the culture of each variety were killed in poison bottle and preserved with expanded wings to study their colour, shape, size and appearance. Twenty five adults of each sex were measured for the length from the head to the tip of abdomen and breadth with wing expanded using millimeter scale.

2.7.1 Pre-oviposition, oviposition and post oviposition periods

A pair of freshly emerged male and female moths (replicated ten times) from pupae was kept separately in rearing cage covered with a fine muslin cloth to study the pre-oviposition, oviposition, post-oviposition periods. Absorbent cotton dipped in 5 per cent honey solution was provided as food for the adults. Fresh tomato leaves and fruits were kept inside the cage for egg laying substrate and they were changed daily. The eggs laid by each female on leaves and fruits were removed daily with the help of fine camel hair brush and total number of eggs laid by each female were recorded separately. The pre-oviposition period was calculated from the date of emergence of female from the pupa and the date of starting of egg laying. Oviposition period was calculated from the date of starting of egg laying to the date of cessation of egg laying by the female. Post-oviposition period was calculated from the date of cessation egg laying to the date of death of the female.

2.7.2 Longevity

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

2.7.3 Fecundity

Number of eggs laid by each female was recorded daily till the death of the female. Average fecundity of each female was worked out separately.

The eggs laid by the females reared on each variety of the tomato under study were examined under a microscope for their colour, shape and size. The length and breadth of thirty eggs were measured with the help of stage and ocular micrometer.

To study the incubation period and hatching percentage of the eggs, thirty freshly laid eggs by the female reared on each variety were observed under microscope daily in the morning till hatching and average incubation period was calculated. The eggs were considered as hatched when tiny larvae were come out from it. Hatching percentage was calculated from the number of eggs hatched out from total number of eggs kept under observation.

2.8 Statistical analysis

The data recorded on the measurements and duration of eggs, different larval instars, pre pupa, pupa, adult male and female and, pre-oviposition, oviposition and post-oviposition periods, sex ratio, mean fecundity and hatching percentage of *H. armigera* were subjected to analysis of variability using standard deviation as the measure of variability.

3. Results and Discussion

3.1 Egg

The freshly laid eggs in experiments conducted during different seasons were nearly hemispherical round shaped with flattened base, giving a shining yellowish white appearance at first and become dark brown prior to hatching. The data presented in Table 1 revealed that the length and breadth of eggs were recorded maximum (0.52 ± 0.02 and 0.53 ± 0.03 mm) for post *Rabi* season, while minimum for *Rabi* season with 0.47 ± 0.02 and 0.50 ± 0.03 mm,

respectively. The corresponding values for pre *Rabi* season was noted as 0.50 ± 0.02 and 0.52 ± 0.03 mm, respectively. In early studies, Patel *et al.* [9] measured the *H. armigera* eggs from 0.45 to 0.51 mm with an average of 0.49 ± 0.04 mm in length and from 0.50 to 0.58 mm with an average of 0.54 ± 0.2mm in width.

Results presented in Table 1 showed that the incubation period of *H. armigera* eggs ranged from 2 to 5 days for all three seasons of experiments. However, average minimum period for eggs hatching was recorded during post *Rabi* season which was 3.43 ± 0.63 days. For rest of the two seasons, the incubation period increased and recorded to be 3.87 ± 0.90 days for pre *Rabi* and 4.60 ± 0.93 days for *Rabi*. The present results are similar to the findings obtained by Jallow and Matsumura [10] where the egg incubation period lasted for 2-6 days on tomato.

3.1.1 Hatching percentage

It is evident from the data in Table 3 that maximum hatching of 90.00 per cent was observed during post *Rabi* season, which was followed by pre *Rabi* season with 83.33 per cent hatching of eggs. The minimum eggs number of that hatched out (76.67 per cent) was recorded during *Rabi* season. The present findings are in close conformity with the findings of Sharma *et al.* [11] who recorded hatchability of 87.80 per cent during pre *Rabi* season, 77.80 per cent during *Rabi* season and 89.00 per cent during post *Rabi* season.

3.2 Larva

In order to study the colour, shape, size and duration of different larval instars of *H. armigera,* the newly hatched larvae were reared on tomato during three different seasons. During the present investigation, larvae of *H. armigera* passed through six instars. In past, Poitout and Cayrol [12], Nachippan and Subramaniam [13] and Patel [14] also observed six distinct larval instars of *H. armigera* on tomato. However, Sharma *et al.* [11] and Kumar *et al.* [15] reported five larval instars of *H. armigera* during the investigation. The variation in larval stages might be attributed due to the variation in nutritional quality of the host plants, adaptability of *H. armigera* population in various geographic regions.

3.2.1 First instar

There was no significant difference observed in colour and shape of first instar larvae during different seasons. The newly hatched larva was semi translucent and yellowish white in colour with yellowish orange longitudinal lines on the dorsal surface of the body. The body length and breadth of first instar larva was noted to be maximum with 1.49 ± 0.03 and 0.52 ± 0.02 mm when reared during post *Rabi* season. It was followed by pre *Rabi* and *Rabi* seasons where the body length and breadth was recorded as 1.47 ± 0.03 and 0.50 ± 0.02 mm and 1.45 ± 0.03 and 0.47 ± 0.02 mm, respectively (Table 1). Kumar *et al.* [15] reported that the length and breadth of first instar larva reared on tomato averaged 1.41 ± 0.06 mm and 0.46 ± 0.01mm, respectively, which corroborate the present findings.

The data in Table 2 indicated that the period of first instar development ranged from 2 to 6 days with a minimum mean time of 2.27 ± 0.52 days was recorded during post *Rabi* season. During pre *Rabi* season the period was somewhat increased and noted as 2.67 ± 0.80 days. The maximum mean developmental period of first instar larvae was recorded during *Rabi* season and it was 3.33 ± 0.71 days. Similar results were also obtained by Sharma *et al.* [11], who recorded the average duration of first instar larva was 2.62 ± 0.50 days on tomato.

3.2.2 Second instar

It was observed during all three seasons that the size of second instar larvae increased and the colour was brownish yellow with black thoracic legs and minute hairy structure on its body surface. Results (Table 1) indicated that post *Rabi* season reared second instar larvae measured maximum body length and breadth of 3.36 ± 0.04 and 0.69 ± 0.03 mm, while it was minimum during *Rabi* season with 3.22 ± 0.03 and 0.63 ± 0.02 mm. The body measurements of second instar noted during pre *Rabi* was 3.29 ± 0.04 and 0.66 ± 0.03 mm, respectively. Earlier, Shivanna *et al.* [16] measured the length of second instar larva as 3.31 to 3.42 mm with an average of 3.36 ± 0.04 mm, which supports the present findings.

The mean development of second instar larvae was recorded to be minimum with an average of 2.77 ± 0.63 days during post *Rabi* season, while it was maximum during *Rabi* season as 3.77 ± 0.94 days. The pre *Rabi* season was intermediate with 2.93 ± 0.78 days of developmental period (Table 2). Bhatt and Patel [17] noted the duration of 2 to 4 days for the development of second instar larvae with an average of 2.88 ± 0.71 days.

3.2.3 Third instar

Second instar larvae moulted to third instar and become longer than the second instar and it has longitudinal lines on body with brownish head. The results followed the same trend and maximum body length and breadth (9.71 ± 0.08 and 2.66 ± 0.06 mm) was observed during post *Rabi* season. It was followed by pre *Rabi* season with 9.52 ± 0.06 and 2.60 ± 0.04 mm, respectively. The minimum length and breadth of third instar larvae was recorded during *Rabi* season, which was 9.26 ± 0.07 and 2.57 ± 0.05 mm, respectively (Table 1). The present findings are in close conformity with the results of Thakor *et al.* [18], who reported the body the body length and breadth of third instar larvae to be 9.63 to 9.73 (Av. 9.65 ± 0.03) mm and 2.69 to 2.81 (Av. 2.74 ± 0.04) mm, respectively.

The data in Table 2 showed that the third instar larvae had minimum developmental period of 3.77 ± 0.68 days during post *Rabi* season. However, mean developmental period increased during pre *Rabi* season (4.13 ± 0.78 days) and reached the maximum with 5.20 ± 0.92 days during *Rabi* season. Parmar [19] noted the duration of third instar larvae from 3 to 6 days with an average of 4.48 ± 1.09 days, which corroborate the present findings.

3.2.4 Fourth instar

No significant change was observed in the fourth instar larvae when reared during the three different seasons. However, variation in colour and number of longitudinal stripes was observed among the larvae. Measurement of fourth instar larvae was recorded to be maximum for post *Rabi* season with an average body length and breadth of 23.08 ± 1.61 and 3.27 ± 0.02, mm, while it was minimum for *Rabi* season with 18.98 ± 1.72 and 3.16 ± 0.03, mm, respectively. During pre *Rabi* season, the average length and breadth of larvae was 20.37 ± 1.59 and 3.20 ± 0.02 mm, respectively (Table 1). However, Sharma *et al.* [11] observed the average length and breadth of fourth instar larva as 17.8 ± 0.34 and 2.99 ± 0.31 mm when reared on tomato.

The developmental period of fourth instar ranged from 4 to 7 days during all three seasons (Table 2). The minimum fourth

instar larval period of 4.63 ± 0.67 days was recorded in post *Rabi* season, while maximum during *Rabi* season with 6.03 ± 0.93 days. During pre *Rabi* season, it was recorded as 4.87 ± 0.78 days. While studying the biology of *H. armigera,* Thakor and Patel [20] recorded the average development period of 4.90 days for the fourth instar larva.

3.2.5 Fifth instar

The colour and shape of the fifth instar larva was noted pale brown with brown lateral stripes and continuous dorsal stripe in all three seasons without any remarkable difference. The head was reddish brown. Results presented in Table 1 showed that post *Rabi* season reared fifth instar larvae had maximum body length and breadth of 33.08 ± 1.96 and 5.14 ± 0.04 mm, which was followed by pre *Rabi* and *Rabi* seasons with an average of 28.83 ± 1.88 and 4.96 ± 0.04 mm and 26.23 ± 2.00 and 4.90 ± 0.04 mm, respectively. The results are also supported by Sharma *et al.* [11] who recorded body length and breadth of 32.40 ± 0.92 and 5.20 ± 0.02 mm on tomato.

The data in Table 2 revealed that fifth instar took minimum time (4.87 ± 0.82 days) to develop during post *Rabi* season. While, it was maximum during *Rabi* season and recorded as 6.83 ± 1.21 days. For pre *Rabi* season, the mean developmental period of fifth instar was noted as 5.70 ± 0.88 days. However, Parmar [19] mentioned that the fifth instar larvae took developmental period from 3 to 7 days with an average of 5.00 ± 1.42 days.

3.2.6 Sixth instar

The body of sixth instar larvae was pale green in colour with scattered short hairs all over it in all three seasons. The thoracic and anal shields and thoracic legs were brown in colour while head of the larvae was observed in reddish brown colour. The shape of sixth instar larva was flattened ventrally but convex dorsally. The measurement of sixth instar larvae was observed maximum during post *Rabi* season with 41.86 ± 1.43 mm length and 6.72 ± 0.49 mm breadth. It was followed in descending order by pre *Rabi* season with 39.19 ± 1.50 and 6.38 ± 0.38 mm and *Rabi* season with 35.00 ± 1.55 and 6.11 ± 0.60 mm, respectively. Similar results were also obtained by Patel *et al.* [9] who measured the sixth instar larvae 40.80 to 46.90 (Av. 43.89 ± 1.24) mm in length and 5.95 to 8.40 (Av. 6.59 ± 0.06) mm in width when reared on rose.

It becomes clear from the data presented in Table 2 that larval development followed the same trend and minimum developmental period of sixth instar was recorded in post *Rabi* season (5.67 ± 0.84 days). Similarly, it was observed maximum during *Rabi* season where the period was noted to be 8.33 ± 1.09 days. It was followed by pre *Rabi* season with 6.67 ± 0.99 days mean sixth instar larval period. Earlier, Thakor and Patel [18] recorded the average development period of the sixth instar as 6.30 days.

3.2.7 Total larval period

It is evident from the data presented in Table 2 that the mean larval period was minimum (23.97 ± 1.96) during post *Rabi* season. It was followed by pre *Rabi* season where the larval period increased to 26.97 ± 2.08 days. The maximum mean larval period was recorded during *Rabi* season with 33.50 ± 2.42 days. There was significant difference in the larval period of *H. armigera* reared during three different seasons. The observations on the life history of *H. armigera* recorded by Sharma *et al.* [11] corroborate the present findings who noted longest larval period of 38.24 days during *Rabi* season, intermediate as 30.39 days during pre *Rabi* season and shortest during post *Rabi* season with 21.50 days. The present results are also in concurrence with the reports of Kumar *et al.* [15] who found prolonged larval period during December to February (*Rabi*) and minimum during February to April (post *Rabi*).

3.3 Pre pupa

The sixth instar larvae after full fed ceased feeding and movement became lighter in colour and crumpled, slender their body. Later on, the colour turned darker with less prominent stripes before formation of pupa. The mean length and breadth of pre-pupae was maximum during post *Rabi* season with 26.93 ± 1.52 and 7.15 ± 0.52 mm which was followed by 25.85 ± 1.72 and 6.58 ± 0.51 mm during pre *Rabi* season and 24.04 ± 1.89 and 6.30 ± 0.65 mm during *Rabi* season, respectively (Table 1). The results of Chaudhary and Sharma [21] supports the present finding, who also recorded length and breadth of pre pupa as 25.40 ± 1.74 mm and 4.95 ± 0.56 mm, respectively.

The data in Table 2 indicated that the pre-pupal period of *H. armigera* varied from 2 to 4 days during three seasons. It was noted to be minimum during post *Rabi* season with 2.10 ± 0.31 days, while maximum during *Rabi* season with 2.90 ± 0.66 days. During pre *Rabi* season, the pre pupal period was recorded as 2.30 ± 0.47 days. These findings are in conformity are in agreement with those of Singh and Singh [22], Ongoren *et al.* [23] and Nachiappan and Subramanium [13].

3.4 Pupa

Close observation indicated that the pupae were broadly rounded interiorly but tapering posteriorly. The newly formed yellowish green pupa became light brown within 24 hours and further darkened prior to emergence of moth in all three experimental seasons. The data presented in Table 1 showed that the measurement of male and female pupae differed for all three seasons. The length and breadth of female pupae were 19.34 ± 1.52 and 6.72 ± 0.45 mm during post *Rabi* season, 18.18 ± 1.23 and 6.38 ± 0.58 mm during pre *Rabi* season and 17.54 ± 1.42 and 6.06 ± 0.61 mm during *Rabi* season, respectively. Similarly, the length and breadth for male pupae were 16.96 ± 1.24 and 6.04 ± 0.73 mm, 16.43 ± 1.05 and 5.83 ± 0.34 mm and 16.06 ± 1.10 and 5.74 ± 0.41 mm during post *Rabi*, pre *Rabi* and *Rabi* seasons, respectively. However, Sharma *et al.* [11] reported that the male and female pupa measured 22.25 ± 0.94 mm and 18.20 ± 0.45 mm in length and 5.98 ± 0.24 mm and 6.42 ± 0.54 mm in breadth, respectively.

Results on pupal period (Table 2) showed that the female took more time to complete pupal development than the male. However, among different seasons, maximum pupal period was recorded during *Rabi* season where male pupae took 10.63 ± 1.19 days and female pupae took 14.23 ± 1.48 days to emerge as adults. It was followed by pre *Rabi* season with 8.63 ± 0.93 days for male and 12.27 ± 1.08 days for female. The minimum pupal period was recorded during post *Rabi* season as 8.27 ± 1.14 days for male and 11.90 ± 1.21 days for female, respectively. Similar observations were also recorded by Sharma [24] and Tripathi and Sharma [25] which support the present findings. However, Sharma *et al.* [26] recorded pupal period of 13.78 to 24.38 days which might be due to climatic variations of the study area.

Table 1: Measurement of various life stages of *H. armigera* reared on tomato during different seasons

Sr. No.	Life Stage	Measurement (mm)	Pre *Rabi*			*Rabi*			Post *Rabi*		
			Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
	Egg	Length	0.48	0.53	0.50 ± 0.02	0.44	0.51	0.47 ±0.02	0.48	0.55	0.52±0.02
		Breadth	0.47	0.58	0.52 ± 0.03	0.46	0.55	0.50±0.03	0.48	0.60	0.53±0.03
2	Larvae										
	I instar	Length	1.42	1.51	1.47 ± 0.03	1.40	1.49	1.45 ± 0.03	1.44	1.53	1.49 ± 0.03
		Breadth	0.48	0.53	0.50 ± 0.02	0.44	0.49	0.47 ± 0.02	0.47	0.54	0.52 ± 0.02
	II instar	Length	3.21	3.35	3.29 ± 0.04	3.18	3.27	3.22 ± 0.03	3.28	3.41	3.36 ± 0.04
		Breadth	0.62	0.71	0.66 ± 0.03	0.58	0.65	0.63 ± 0.02	0.64	0.72	0.69 ± 0.03
	III instar	Length	9.44	9.66	9.52 ± 0.06	9.10	9.40	9.26 ± 0.07	9.58	9.86	9.71 ± 0.08
		Breadth	2.54	2.68	2.60 ± 0.04	2.48	2.64	2.57 ± 0.05	2.55	2.80	2.66 ± 0.06
	IV instar	Length	17.29	23.00	20.37 ± 1.59	15.65	22.66	18.98 ± 1.72	20.13	25.84	23.08 ± 1.61
		Breadth	3.15	3.24	3.20 ± 0.02	3.12	3.23	3.16 ± 0.03	3.22	3.30	3.27 ± 0.02
	V instar	Length	26.03	32.36	28.83 ± 1.88	23.46	29.69	26.23 ± 2.00	30.12	36.45	33.08 ± 1.96
		Breadth	4.82	4.99	4.96 ± 0.04	4.76	4.93	4.90 ± 0.04	5.00	5.17	5.14 ± 0.04
	VI instar	Length	36.16	42.12	39.19 ± 1.50	32.22	37.56	35.00 ± 1.55	39.32	44.66	41.86 ± 1.43
		Breadth	5.68	6.97	6.38 ± 0.38	4.96	7.16	6.11 ± 0.60	6.14	8.40	6.72 ± 0.49
3	Pre-pupa	Length	22.26	28.67	25.85 ± 1.72	21.03	27.92	24.04 ± 1.89	25.15	31.04	26.93 ± 1.52
		Breadth	5.55	7.43	6.58 ± 0.51	4.46	7.24	6.30 ± 0.65	6.43	8.18	7.15 ± 0.52
4	Pupa										
	Male	Length	14.54	18.80	16.43 ± 1.05	13.77	18.40	16.06 ± 1.10	14.64	18.94	16.96 ± 1.24
		Breadth	5.16	6.70	5.83 ± 0.34	5.02	6.52	5.74 ± 0.41	5.20	7.55	6.04 ± 0.73
	Female	Length	16.32	20.34	18.18 ± 1.23	15.43	20.54	17.54 ± 1.42	16.54	22.78	19.34 ± 1.52
		Breadth	5.40	7.16	6.38 ± 0.58	5.00	7.49	6.06 ± 0.61	6.15	8.11	6.72 ± 0.45
5	Adult										
	Male	Length	13.33	16.53	15.01 ± 0.84	13.57	16.45	14.70 ± 0.85	15.00	17.45	15.69 ± 0.58
		Breadth	30.19	35.94	32.93 ± 1.77	29.23	34.26	31.96 ± 1.43	31.95	37.08	33.89 ± 1.58
	Female	Length	16.75	19.67	18.31 ± 0.91	16.08	18.99	17.69 ± 0.94	18.04	19.96	19.16 ± 0.55
		Breadth	33.84	38.73	36.37 ± 1.17	31.75	36.38	33.98 ± 1.23	36.23	40.87	38.13 ± 1.14

Table 2: Comparative biology of *H. armigera* on tomato during different seasons

Sr. No.	Life stage	Pre *Rabi*			*Rabi*			Post *Rabi*		
		Period (Days)								
		Min	Max	Mean ± S.D.	Min	Max	Mean ± S.D.	Min	Max	Mean ± S.D.
1	Egg	2	5	3.87 ± 0.90	2	5	4.60 ± 0.93	2	4	3.43 ± 0.63
2	Larva									
	I instar	2	4	2.67 ± 0.80	3	6	3.33 ± 0.71	2	4	2.27 ± 0.52
	II instar	2	4	2.93 ± 0.78	3	6	3.77 ± 0.94	2	4	2.77 ± 0.63
	III instar	3	5	4.13 ± 0.78	4	7	5.20± 0.92	3	5	3.77 ± 0.68
	IV instar	4	6	4.87 ± 0.78	5	8	6.03 ± 0.93	4	6	4.63 ± 0.67
	V instar	4	7	5.70± 0.88	5	9	6.83± 1.21	4	7	4.87± 0.82
	VI instar	5	8	6.67± 0.99	6	10	8.33±1.09	5	8	5.67 ± 0.84
	Total	23	30	26.97± 2.08	28	39	33.50±2.42	21	28	23.97 ± 1.96
3	Pre-pupa	2	3	2.30± 0.47	2	4	2.90± 0.66	2	3	2.10± 0.31
4	Pupa									
	Male	7	10	8.63 ± 0.93	8	13	10.63 ± 1.19	6	10	8.27 ± 1.14
	Female	9	14	12.27 ± 1.08	10	17	14.23 ± 1.48	9	14	11.90 ± 1.21

3.5 Adult

The colour of adults was observed more or less similar during all three seasons. However, the size of the adults varied and smaller adults were noted during *Rabi* season. The medium sized adults possessed yellowish brown forewings with series of the dots on margin. There was black kidney shaped mark on underside of each forewing. Hind wings were light in colour and each possessed a dark colour patch at the apical end. Morphologically, both male and female were closely resembled to each other except female had tuft of hairs on the tip of the abdomen.

It was observed that the females were larger than the male with respect to length and breadth of the body. However, the measurements body length and breadth of male and female reared during three different seasons was recorded to be maximum during post *Rabi* season with 15.69 ± 0.58 and 33.89 ± 1.58 mm and 19.16 ± 0.55 and 38.85 ± 1.04 mm, respectively. It was followed by pre *Rabi* season where the body measurements were noted as 15.01 ± 0.84 and 32.93 ± 1.77 mm for male and 18.31 ± 0.91 and 36.37 ± 1.17 mm for female, respectively. The minimum length and breadth of male and female was recorded during *Rabi* season with 14.70 ± 0.85 and 31.96 ± 1.43 mm and 17.69 ± 0.94 and 34.92 ± 1.32 mm, respectively. In early reports Singh and Singh (1975), Atwal and Dhaliwal [27] and Parmar [19] reported similar colour, shape and size of adults of *H. armigera.*

3.5.1 Longevity

Results (Table 3) showed that female lived for longer time than the male in all three seasons under study. The female longevity varied from 7 to 11 days with an average of 9.80 ± 1.32 days during post *Rabi* season, 8.50 ± 1.18 days during

pre *Rabi* season and 7.70 ± 1.34 days during *Rabi* season. Likewise, the males lived with a range of 4 to 7 days and mean longevity was recorded as 5.80 ± 0.92 days during post *Rabi* season, 5.30 ± 0.95 days during pre *Rabi* season and 4.90 ± 0.88 days during *Rabi* season, respectively. The outcomes of the present investigation are comparable to the results of Parmar [19] and Thakor and Patel [20]. The results are also supported by the studies of Bhatt and Patel [17] who observed that female lived longer than the male.

3.5.2 Pre-oviposition
The data presented in Table 3 indicated that the female had pre-oviposition period of 2 to 4 days. However, the minimum mean pre-oviposition period (1.90 ± 0.57 days) was recorded during *Rabi* season and maximum (3.10 ± 0.88 days) during post *Rabi* season. During pre *Rabi* season, it was noted 2.40 ± 0.70 days. These findings are in agreement with those of Patel [14] and Kumar *et al.* [15].

3.5.3 Oviposition
It is evident from the Table 3 that female oviposited for 4 to 8 days during all three seasons. However, the maximum mean oviposition period (6.20 ± 1.14 days) was recorded during post *Rabi* season. It was followed by *Rabi* and pre *Rabi* seasons, where the oviposition period was observed to be 5.40 ± 0.84 and 5.30 ± 1.06 days, respectively. The observations on oviposition period corroborate with those of Sharma *et al.* [11].

3.5.4 Post oviposition
It was observed that female moths lived for 0 to 2 days after completion of egg laying. The maximum post-oviposition period of 0.80 ± 0.42 days was recorded during pre *Rabi* season, which was followed by post *Rabi* season (0.50 ± 0.53 days) and *Rabi* season (0.40 ± 0.52 days). Similar observations on post-oviposition period were also recorded by Parmar (2006) who stated that the female lived for 0 to 2 days after oviposition. However, Thakor *et al*. [18] mentioned that post-oviposition period was ranged from 1 to 2 days.

3.5.5 Fecundity
It becomes clear from the Table 3 that number of eggs laid by females reared during three different seasons varied considerably. The maximum mean fecundity of 204.70 ± 13.20 eggs was recorded during post *Rabi* season. It was followed in decreasing order by pre *Rabi* and *Rabi* seasons with 189.20 ± 13.01 and 154 ± 11.80 eggs, respectively. Sharma *et al.* [11] and Kumar *et al.* [15] also noted maximum egg lying capacity of *H. armigera* during post *Rabi* period, which is in agreement with the present findings.

3.5.6 Sex ratio
Under laboratory conditions, the sex ratio of male and female was recorded to be 1: 0.80, 1: 0.75 and 1: 1.07 during pre *Rabi*, *Rabi* and post *Rabi* seasons (Table 3). The present findings are in agreement with the results of Kumar *et al.* [15] who recorded sex ratio during pre *Rabi, Rabi* and post *Rabi* period as 1:0.78, 1:0.69 and 1:1.23.

3.6 Growth index
The data presented in Table 3 clearly indicated that the pest *H. armigera* grew well during post *Rabi* season and the growth index was obtained maximum as 4.03. It was followed by pre *Rabi* season (3.34) and *Rabi* season (2.59). On the basis of growth index of *H. armigera* during different seasons, the order of suitability for growth and multiplication was post *Rabi* season> pre *Rabi* season> *Rabi* season.

Table 3: Pre-oviposition, oviposition, post-oviposition periods, fecundity, longevity, growth index, hatching percentage and sex ratio of *H. armigera* on tomato during different seasons

Sr. No.	Life stage	Pre *Rabi*			*Rabi*			Post *Rabi*		
		Period (Days)								
		Min	Max	Mean ± S.D.	Min	Max	Mean ± S.D.	Min	Max	Mean ± S.D.
1	Adult									
	Pre-oviposition	2	4	2.40 ± 0.70	1	3	1.90 ± 0.57	2	4	3.10 ± 0.88
	Oviposition	4	7	5.30 ± 1.06	4	7	5.40 ± 0.84	4	8	6.20 ± 1.14
	Post oviposition	0	2	0.80 ± 0.42	0	1	0.40 ± 0.52	0	1	0.50 ± 0.53
2	Longevity									
	Male	4	7	5.30± 0.95	4	6	4.90± 0.88	5	7	5.80± 0.92
	Female	7	11	8.50 ± 1.18	7	11	7.70 ± 1.34	7	11	9.80 ± 1.32
3	Fecundity	166	206	189.20 ± 13.01	133	171	154.00 ± 11.80	186	226	204.70 ± 13.20
4	Growth index	3.34			2.59			4.03		
5	Hatching (%)	83.33			76.67			90.00		
6	Sex ratio (M:F)	1: 0.80			1: 0.75			1: 1.07		

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