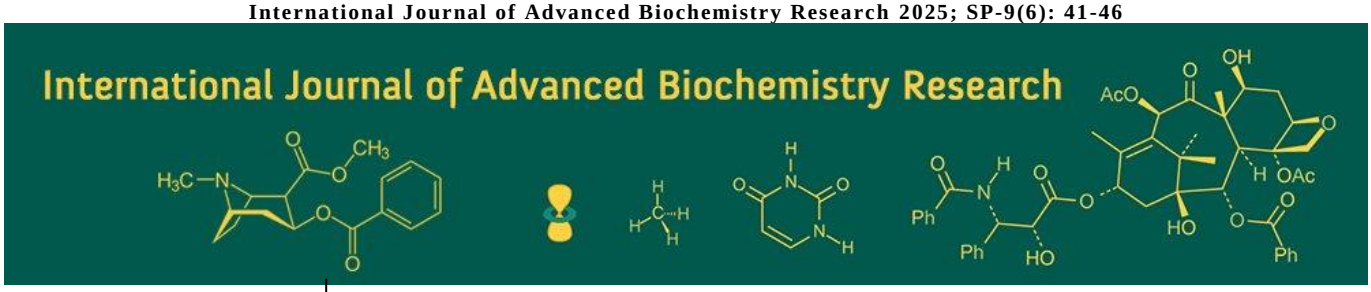

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Biology of melon fruit fly *Bactrocera cucurbitae* (Coquillett) on cucumber

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Abstract
Laboratory studies on the biology of the melon fruit fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae), on cucumber revealed that the average incubation period was 1.36±0.48 days, with an egg hatching percentage of 84%. The average durations of the first, second, and third instar maggots were 1.52±0.50, 2.18±0.48, and 3.02±0.47 days, respectively. The total larval period varied from 5 to 9 days, with an average of 6.72±0.73 days. The pre-pupal and pupal periods averaged 0.79±0.27 days and 6.74±0.69 days, respectively. The pre-oviposition, oviposition, and post-oviposition periods were 10.14±1.21, 4.79±1.17, and 1.64±0.62 days, respectively. Female fecundity averaged 64.83±12.69 eggs. The average longevity of male and female adults was 13.73±1.86 days and 16.57±1.53 days, respectively. The total life span on cucumber was 29.25±1.93 days for males and 32.27±2.13 days for females, with a recorded sex ratio of 1:1.33 (male: female).

Keywords: *Bactrocera cucurbitae*, melon fruit fly, cucumber, life cycle, fecundity, maggot instars, pupation, insect rearing, biology, Tephritidae, sex ratio, trinocular microscope

Introduction
Cucumber (*Cucumis sativus* L.), a member of the family *Cucurbitaceae*, belongs to a group that comprises 118 genera and 825 species (Laila *et al.*, 2015) [7]. It is believed to have originated in India, where a significant amount of genetic diversity has been documented. In India, cucumber is predominantly cultivated from the last week of January to February.

Several insect pests are commonly associated with cucumber cultivation, including the melon fruit fly, red pumpkin beetle, pumpkin caterpillar, American serpentine leaf miner, and aphids. While many of these pests can attack the plant at various growth stages, some are more severe during specific phases. For instance, pests like the red pumpkin beetle, leaf miner, and flea beetle are particularly destructive at the seedling stage, whereas the fruit fly becomes a major concern during the fruiting stage (Ram *et al.*, 2009) [15].

The family *Tephritidae* (true fruit flies) is one of the largest, most diverse, and biologically significant families within the order Diptera, encompassing over 4,200 known species distributed across 471 genera (Norrbom *et al.*, 1999) [11]. The melon fruit fly, *Bactrocera cucurbitae*, was first reported in India by Bezzi (1913) [2].

The economic impact of fruit flies is considerable, involving not only direct yield losses and increased pest control costs but also indirect effects such as the loss of export markets and expenditures on the construction and maintenance of quarantine and fruit treatment facilities due to strict international regulations (Anon., 1988) [18]. *B. cucurbitae* poses a serious threat to intensive agriculture. Therefore, understanding the biology and seasonal status of this pest is crucial for designing effective pest management strategies, particularly within integrated farming systems.

Materials and Methods
The present laboratory investigation on the biology of the melon fruit fly, *Bactrocera cucurbitae* (Coquillett), infesting cucumber was carried out at the Department of Entomology, B.A. College of Agriculture (BACA), Anand Agricultural University (AAU), Anand, during the summer of 2023.

Rearing Technique

The initial culture of *B. cucurbitae* was established by collecting naturally infested cucumber fruits from the field. The infested fruits were placed in galvanized cages (36 × 12 cm) over a 5.00 cm thick layer of sieved moist sand to facilitate puparium formation. The top of each cage was covered with white muslin cloth to prevent the escape of maggots. After 4-5 days, the sand was sieved to collect the pupae.

The collected puparia were transferred to a plastic bowl containing moist sand and placed inside a plastic rearing cage (30 × 30 × 45 cm) to allow adult emergence. Freshly emerged adult males and females were paired and confined in rearing cages. A cotton swab soaked in a 5% sugar solution along with semi-solid Protein-X powder was provided as a food source. A physiologically mature cucumber fruit was placed inside the cage to facilitate oviposition.

Eggs laid inside the cucumber fruit were gently extracted using a fine camel hair brush and transferred to small cucumber slices. These slices, each containing 10 eggs, were placed into five separate glass Petri plates. Upon hatching, neonate maggots were transferred with a fine camel hair brush into aerated plastic vials, each containing fresh cucumber slices.

When maggots stopped feeding and became inactive (pre-pupal stage), they were transferred to plastic vials with a bottom layer of moist sand for pupation. The vials were covered to prevent maggot escape. Upon adult emergence, a single male-female pair was confined in a rearing cage (30 × 30 × 45 cm). Absorbent cotton dipped in 5% honey solution was provided as a food source, along with a small cucumber fruit for oviposition and resting.

Method of Observations on Life Stages

- **Incubation Period:** Calculated from the date of egg laying to the date of hatching.
- **Egg Hatching Percentage:** Determined by the number of eggs hatched out of the total number of eggs laid.
- **Maggot Period:** Recorded from egg hatching to the pre-pupal stage.
- **Maggot Instars:** Individual maggots were observed daily to identify molting stages, confirmed by changes in size and color.
- **Pre-Pupal Period:** Calculated from the onset of maggot inactivity to the formation of the puparium.
- **Pupal Period:** Measured from puparium formation to adult emergence.
- **Pre-Oviposition Period:** From female emergence to the start of egg laying.
- **Oviposition Period:** From the first day of egg laying to its cessation.
- **Fecundity:** Total number of eggs laid by a female during her lifespan.
- **Post-Oviposition Period:** From cessation of egg laying to the death of the female.
- **Sex Ratio:** Determined by separating male and female adults based on the presence (female) or absence (male) of the ovipositor and size.
- **Longevity:** Duration from adult emergence to death, calculated separately for males and females.
- **Total Life Span:** Time from egg laying to the death of the adult fly.

Results and Discussion

Egg

The mature female of *Bactrocera cucurbitae* punctured the surface of young cucumber fruits using its ovipositor, penetrating approximately 2-3 mm deep, and laid eggs in clusters of 5-9. The freshly laid eggs appeared shiny white, translucent, with a tapering end, elongated elliptical shape, and were nearly flat on the ventral side, resembling a curved rice grain.

As presented in Table 1, the mean incubation period of eggs laid by B. cucurbitae on cucumber was 1.36±0.48 days, with a range of 1 to 2 days. The present observations are in agreement with Patel (2005) [12], who reported that the eggs were glistening white, slightly curved, elongated, and tapering towards the end when reared on bitter gourd. Desai *et al.* (2018) [6] reported an incubation period of 1.40 days on cucumber, while Patel and Patel (2018) [13] recorded 1.32±0.47 days on bottle gourd. These results are in close agreement with the current findings.

Hatching Percentage

As shown in Table 1, the hatching percentage of B. cucurbitae eggs on cucumber was found to be 84%. Mir *et al.* (2014) [10] reported an average hatchability of 86.1±0.54%. Similarly, Prasad *et al.* (2018) [14] and Chaudhary *et al.* (2024) [3] found hatchability rates of 87.5±2.5% and 81.41±3.62%, respectively. These findings are more or less comparable with the present study.

Maggot

During the study, it was observed that the maggots were apodous and passed through three distinct instars before entering the pre-pupal stage when reared on cucumber.

First Instar Maggot

First instar maggots were elongated and transparent with a pointed head containing small mandibular hooks. The average duration of the first instar was 1.52±0.51 days, ranging from 1 to 2 days. Patel (2005) [12] recorded a similar duration of 1.65±0.67 days on bitter gourd. Das *et al.* (2017) [5] found it to be 1.4±0.55 days on pumpkin, which confirms the present finding.

Second Instar Maggot

In the second instar, the maggot size increased, the body appeared creamy-white, and the shape became ellipsoidal. The average duration of this stage was 2.17±0.49 days, ranging from 1 to 3 days. Patel and Patel (2018) [13] reported the second instar duration as 1.64±0.49 days on bitter gourd, 1.72±0.45 days on bottle gourd, and 1.68±0.476 days on watermelon. The slight variation may be due to differences in host plants.

Table 1: Biology of melon fruit fly, *B. cucurbitae* under laboratory condition

Life stages	Duration in day(s)			Sample Size (n)
	Minimum	Maximum	Mean±SD	
Egg				
Hatching (%)	84%			50
Incubation period	1	2	1.36±0.48	50
Maggot period				
First instar	1	2	1.52±0.50	50
Second instar	1	3	2.18±0.48	50
Third instar	2	4	3.02±0.47	50
Total maggot period	6	9	6.72±0.73	50
Pre-pupal period	0.5	1.5	0.79±0.27	50
Pupal period	6	9	6.74±0.69	50
Pre-oviposition Period	8	12	10.14±1.21	28
Oviposition period	2	7	4.79±1.17	28
Post-oviposition period	1	3	1.64±0.62	28
Fecundity (Eggs/female)	46	94	64.83±12.69	28
Adult period				
Male	11	17	13.73±1.86	22
Female	12	19	16.57±1.53	28
Total life span				
Male	26	34	29.25±1.93	18
Female	28	37	32.27±2.13	24
Sex ratio (Male: Female)	1: 1.33			

Third Instar Maggot

Third instar maggots were more yellowish and opaque compared to earlier stages. They exhibited a peculiar jumping behavior as a defense mechanism. The fully grown maggots were twelve-segmented. The duration of this stage ranged from 2 to 4 days, with a mean of 3.02±0.47 days. Manzar and Srivastava (2009) [9] reported a similar duration of 3.2±0.21 days. Patel and Patel (2018) [13] and Sowmiya *et al.* (2021) [17] reported 3.32±0.62 and 4.3±0.85 days, respectively, which might differ due to host variation and environmental conditions.

Total Maggot Period

According to Table 1, the total maggot stage lasted between 6 to 9 days, with an average of 6.72±0.73 days. This aligns with the findings of Chaudhry (2023) [4], who reported 6.70±0.66 days, and Manzar and Srivastava (2009) [9], who recorded 5.9±0.97 days. However, Salman and Huggers (2019) [16] reported a longer duration of 12.08±0.98 days on cucumber, likely due to host and climatic differences.

Nature of Damage

The female melon fruit fly damages the crop by depositing eggs inside the fruit and soft vegetative parts of cucumber. After hatching, the maggots bore into the fruit, leading to a water-soaked appearance in mature fruits. Young fruits often become deformed and drop prematurely. The tunnels created by maggots also serve as entry points for secondary infections by fungi and bacteria, causing decay. Additionally, maggots may infest the stems and buds, further damaging the crop.

Pre-pupal Period

After exiting the infested fruits by coiling itself, the third instar maggot of Bactrocera cucurbitae (melon fruit fly) became inactive, sluggish, and ceased feeding. The pre-pupal duration ranged from half a day to one and a half days, with a mean of 0.79±0.25 days.

Laskar (2013) [8] documented that the pre-pupal stage lasted for 0.70±0.27 days. Similarly, Akter and Sohel (2020) [1], as well as Sowmiya *et al.* (2021) [17], reported pre-pupal periods of 0.74±0.28 and 0.70±0.25 days, respectively. Hence, the current findings are generally consistent with previous research.

Pupal Period

The mature maggot transformed into a pupa by forming a protective covering, or puparium, from its third instar maggot skin. This transformation leaves characteristic markings on the puparium. Initially, the puparium appears pale brown, gradually turning reddish-brown or yellowish-brown at the time of eclosion. No morphological differences were observed between male and female pupae of B. cucurbitae. Data presented in Table 1 indicate that the pupal period ranged from 6 to 9 days, with an average of 6.74±0.73 days. Gaddakeri and Rolania (2020) [19] and Chaudhary *et al.* (2024) [3] reported similar durations of 6.90±0.87 and 6.95±0.89 days, respectively. Therefore, the current results are in line with earlier findings.

Sex Differentiation and Sex Ratio

Mature individuals were classified by sex based on morphological characteristics. The male-to-female sex ratio was 1:1.33 (Table 1).

This observation is consistent with previous findings:

- Mir *et al.* (2014) [10]: 1.10±0.14
- Gaddakeri & Rolania (2020) [19]: 1:0.84
- Chaudhary *et al.* (2024) [3]: 1:1.60±0.94

Pre-oviposition Period

The average pre-oviposition period of B. cucurbitae reared on cucumber was 10.25±1.19 days, ranging from 8 to 12 days (Table 1). Patel and Patel (2018) [13] reported a pre-oviposition period of 11.67±0.50 days, while Chaudhary *et al.* (2024) [3] observed 10.30±1.22 days. These results are closely aligned with the present study.

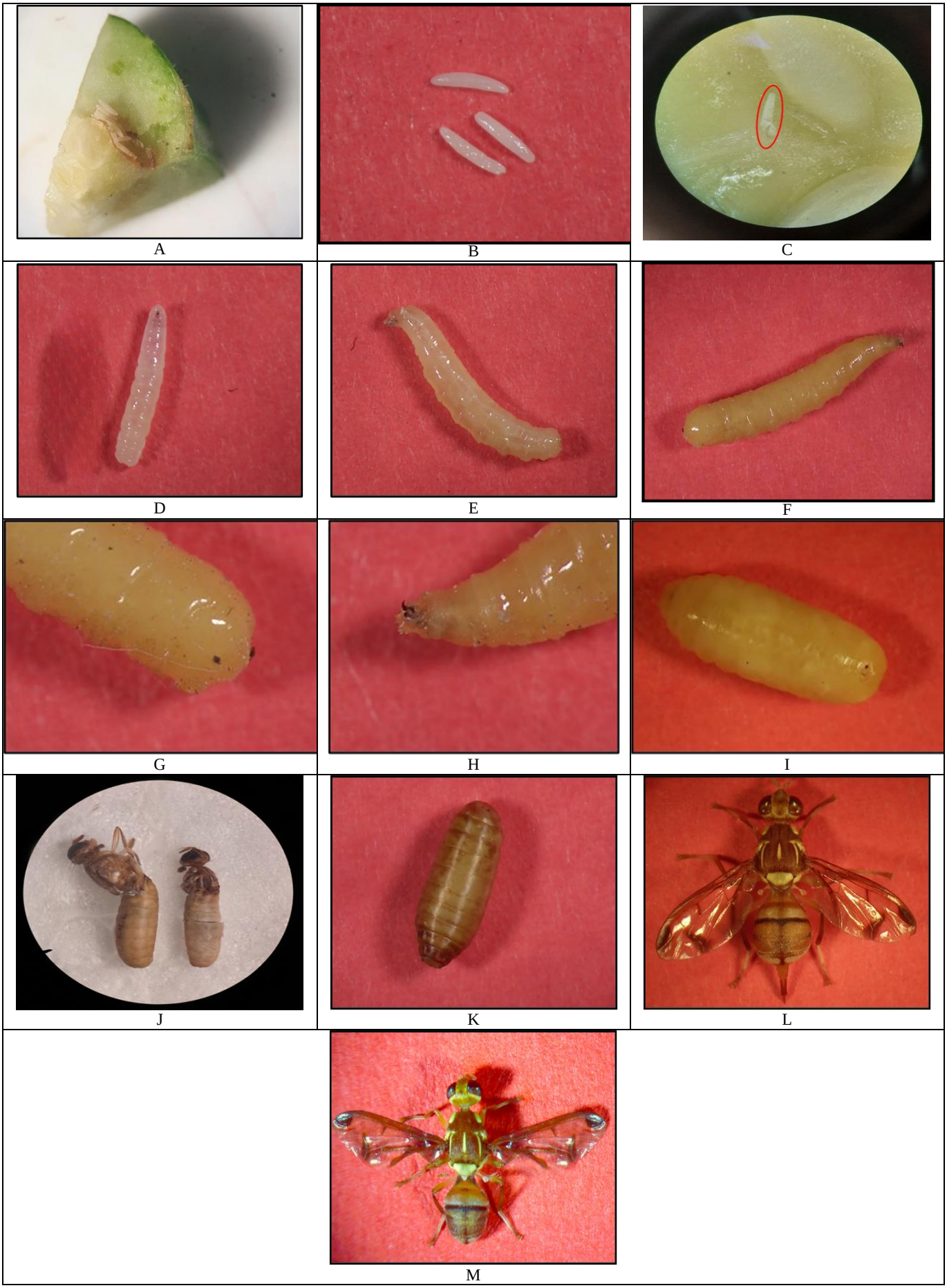

Plate A-M: Life stage of *Bactrocera cucurbitae*.

A. Eggs in cucumber pulp, B. Individual egg, C. Newly hatched egg, D. First instar, E. Second instar, F. Third instar, G. Posterior end of third instar maggot, H. Anterior end of third instar maggot, I. Pre-pupal stage, J. Emergence of adult from pupa (Eclosion), K. Pupal stage, L. Adult female fly with sharp ovipositor, M. Adult male fly

Oviposition Period

The oviposition period ranged from 2 to 7 days, with an average of 4.71±1.16 days on cucumber (Table 1). Desai *et al.* (2018) [6] observed 2.3 days on cucumber, while Patel and Patel (2018) [13] reported 3.60±0.70 days on bottle gourd. Chaudhary *et al.* (2024) [3] reported 4.90±1.33 days on cucumber, which closely aligns with the current study. Variations may be due to differences in host plants and environmental conditions.

Post-oviposition Period

The post-oviposition period of B. cucurbitae reared on cucumber averaged 1.63±0.58 days, ranging from 1 to 3 days (Table 1). Patel and Patel (2018) [13] reported a post-oviposition period of 1.89±0.78 days, while Chaudhary *et al.* (2024) [3] observed 1.75±0.79 days. These findings are consistent with the present results.

Fecundity

Fecundity (number of eggs laid per female) ranged from 46 to 94 eggs, with an average of 64.83±12.69 eggs (Table 1). Mir *et al.* (2014) [10] reported 58-92 eggs per female, while Patel and Patel (2018) [13] recorded a much lower range of 42-46 eggs. Salman and Huger (2019) [16] reported 60.4±4.8 eggs per female on cucumber. Differences in fecundity may be attributed to host type or nutritional and environmental factors.

Adult Longevity

Adult fruit flies are moderately sized and exhibit three reddish-brown or lemon-yellow curved markings (vittae) on the mesothorax, along with a characteristic black "T"-shaped mark at the base of the abdomen. Females are distinguished by a tapering abdomen extending into a pseudo-ovipositor, whereas males have a blunt abdomen. According to Table 1, male longevity ranged from 11 to 17 days with an average of 13.89±1.88 days, and female longevity ranged from 12 to 19 days with an average of 16.58±1.59 days.

Manzar and Srivastava (2009) [9] reported 13.09±2.37 days for males and 15.56±2.67 days for females on bitter gourd. Sharma *et al.* (2019) documented 13±2.41 days (males) and 15.5±3.49 days (females), while Chaudhary *et al.* (2024) [3] observed 13.75±2.40 days (males) and 17.00±2.20 days (females) on cucumber. The current findings are thus in agreement with earlier studies.

Total Life Cycle

The complete life cycle of *B. cucurbitae* from egg to adult was studied under laboratory conditions on cucumber.

- Male fruit flies completed development in 25 to 34 days with an average of 29.42±2.04 days.
- Female fruit flies took 28 to 37 days, with an average of 32.23±2.18 days (Table 1).

Patel (2005) [12] observed developmental durations of 25.15±2.79 days for males and 31.65±2.48 days for females on bitter gourd. Sisodiya (2007) [20] recorded 27.80 days for males and 35.00 days for females on smooth gourd. Akter and Sohel (2020) [1] reported a total developmental period of 36.00±1.69 days. Laskar (2013) [8] noted a total life span of 46.00±10.34 days for males and 48.20±6.93 days for females on bitter gourd, and 43.30±8.62 days (males) and 46.70±9.27 days (females) on pumpkin. Chaudhary *et al.* (2024) [3] reported 34.78±1.56 days for males and 38.23±2.80 days for females. The discrepancies in findings may be attributed to differences in host species, nutritional availability, and climatic conditions.

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