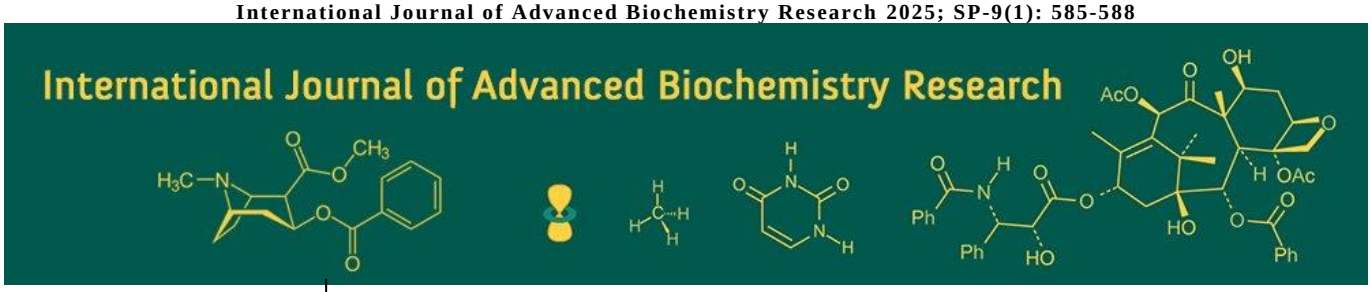

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Developmental biology of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) on eggplant under laboratory conditions

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Abstract
During the 2022 *kharif*, laboratory-based studies on the biology of the shoot and fruit borer, *Leucinodes orbonalis* Guenee in brinjal, were conducted at the Department of Entomology, S.K.N., College of Agriculture, SKNAU, Jobner (Rajasthan). Laboratory-based biological investigations of L. orbonalis on brinjal (Varieties "Pusa Purple Round"), the eggs were oval, flat, and cream-colored before hatching. They then turned pale orange with distinct black spots. The average fecundity was found to be 216.60 eggs. The mean of incubation period and longevity of larval stage (I-instar, II-instar, III-instar, IV-instar and V-instar), pupal and adult stage (male & female) were 3.90, 20.10 (4.20, 4.40, 4.10, 3.70 and 3.70), 6.80, 4.08, (3.67 & 4.50) days respectively. These results offer enough insight into insect biology to enable the implementation of appropriate control strategies.

Keywords: Shoot and fruit borer, *Leucinodes orbonalis*, brinjal, biology, *kharif*, fecundity

1. Introduction
Brinjal (*Solanum melongena* L.) is an Indian vegetable also known as aubergine, garden egg and aubergine. It belongs to the Solanaceae family. Because of its versatility in Indian cuisine, it has been dubbed the "king of vegetables" by Choudhary and Gaur (2009) [5]. It is a major vegetable crop that provides a range of vitamins and minerals. In India, it is grown on 758 million hectares with an annual production of 13.15 million metric tonnes and a productivity of 17400 kg/hectare (Anonymous, 2021) [1]. It grows across India, especially in West Bengal, Orissa, Bihar, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Tamil Nadu, Maharashtra, Rajasthan, and Assam. Rajasthan is one of the main states, covering 5.138 million hectares and producing 23.35 million tonnes with a yield of 4540 kg per hectare (Anonymous, 2022) [2]. During the summer and rainy season, Rajasthan's brinjal growing districts include Jodhpur, Sri Ganganagar, Jaipur, Alwar, and Kota. There are several causes of decreased brinjal yield, but one of the most important is damage caused by insect pests. It is attacked by a variety of insect pests from the nursery stage to harvest (Regupathy *et al.*, 1997) [12]. It is infected with 26 different insect and non-insect pest species. Among insect pests, shoot and fruit borer, *Leucinodes orbonalis* Guen., is a serious impediment to obtaining potential production. The study of biology identifies the weakest link in a pest's life cycle at which effective control methods may be performed. So, in the current study, an experiment was designed to investigate the various developmental periods and phases of the brinjal shoot and fruit borer life cycle under laboratory circumstances.

2. Materials and Methods
The first culture of shoot and fruit borer, *L. orbonalis*, was taken from infected fruits of an unsprayed brinjal crop seeded at Horticulture farm, S.K.N., College of Agriculture, SKNAU, Jobner (Rajasthan) in the second week of August, 2022.

2.1 Maintenance of laboratory culture
Fresh brinjal fruits were chopped into little pieces and placed in a glass tube every day to feed the growing larvae. The glass tubes were then closed with cotton plugs, and the food

was changed daily in the morning to avoid fungal contamination until the fifth instar larvae were ready to pupate. Because the larvae dined on brinjal pieces by tunnelling and excreting exuviae, the food in the glass tubes had to be changed on a regular basis. When the fifth instar larvae were ready to pupate, they were transferred to a glass jar containing sand and covered with muslin fabric for pupation. To ensure pupae survival, the sand in the jar was maintained wet by dusting it with water. The sand was autoclaved to avoid pathogenic contamination of the pupae. On the same day, the adults that emerged from pupae were sexed based on their body size and the presence of a tuft of hair at the tip of the abdomen. These mature moths were employed in subsequent experiments. One pair of newly emerged male and female moths were released into a glass jar (15 cm × 10 cm) with damp filter paper at the bottom. Fifteen similar glass jars were produced, with five jars in each replication and three replications per case. The glass jars were then covered with black paper from the outside, and cotton swabs dipped in 5% honey solution were strung from the upper side using pins to give sustenance for the adults. The mouths of the glass jars were covered with muslin linen. A 50 ml plastic vial with a brinjal plant twig soaked in water was also placed in the glass jar to create a natural habitat for adults to oviposit in. The eggs retrieved were checked daily to determine the incubation duration of the eggs as well as the appearance of newborn larvae. To record the incubation duration, three replications of 10 eggs each were performed. The larvae that emerged from the eggs on the same day were employed in biological experiments. All parameters were measured at room temperature and relative humidity in three distinct months: August, September, and October. In August, September, and October, average temperatures were 30.30 °C, 33.10 °C, and 32.70 °C, with relative humidity levels of 59.00, 50.00, and 51.00 percent, respectively.

2.2 Biological parameters studied

2.2.1 Incubation period

To track the incubation period, newly deposited eggs were checked daily for the appearance of neonates.

2.2.2 Larval period

Ten neonate larvae were put into tiny glass tubes containing pollen grains from brinjal flowers using a damp camel hair brush. The food in the glass tube was replaced every morning to avoid fungal development on the meal. When the second instar larvae formed, the meal was changed from pollen to brinjal slices since the brinjal shoot and fruit borer is an internal feeder that eats by tunnelling into the fruit. When full-grown larvae stopped eating and were inactive, the larval stage was regarded over and the pupal stage began.

2.2.3 Pupal period

The fully developed fifth instar larvae were moved to glass jars with a wet layer of autoclaved sand and examined daily in the morning to research the pupal stage throughout the year.

2.2.4 Fecundity

The individuals that emerged were sexed by looking for tufts of hair at the end of the abdomen and measuring their body size. The men were smaller and did not have an abdominal tuft. Females were bigger and possessed tufts of fur on the apex of their abdomens. One pair was released in each glass jar (15 cm x 10 cm) covered with black chart on the outside, and cotton swabs dipped in 5% honey solution were suspended from the upper side with pins to offer food to the adults. These partners were monitored daily to study adult fecundity. The fecundity was determined by counting the number of eggs laid by the female on damp filter paper, glass jar, brinjal leaves on a twig put in the jar, and muslin fabric.

2.2.5 Adult longevity

To evaluate the lifespan of adults, both male and female, observations were made daily from their emergence till death.

2.2.6 Statistical analysis

The biological data on brinjal shoots and fruit borer on brinjal were statistically analysed.

3. Results and Discussion

3.1 Incubation Period

The eggs were placed in groups of 5 to 6 or individually on the underside of brinjal leaves or on muslin linen. Freshly deposited eggs were oval-shaped and creamy white in hue. When the egg was about to hatch, it turned a rich orange hue with a noticeable black patch at the tip, indicating the growing head of the larva. Table -1 shows that the incubation time ranged from 3 to 4 days, with an average of 3.90±0.32. These findings closely resemble those of Singla *et al.* (2018) [15] and Patel *et al.* (2018) [4]. The observed incubation period ranges from 3 to 4 days, with an average length of 3.90±0.32. The current findings are also broadly consistent with Nayak (2022) [10], who found an average incubation duration of 3.81 days.

3.2 Larva

To explore the several larval instars of *Leucinodes orbonalis* in laboratory conditions, newly born larvae were maintained separately on brinjal leaves and then on fresh fruits until pupation. The larvae moulted four times and went through five instars. The number of moults, as evidenced by exuviae created during moulting, defined the larval stages. The newly born larvae were creamy white in hue. The fully developed larva was seen to be cylindrical and pinkish in hue. The larva's head was dark brown with robust mandibles for mastication. The larva's thorax was divided into three different segments, each with two well-developed thoracic legs. The abdomen had ten segments and five pairs of prolegs detected throughout the investigation, which is consistent with the findings of Singla *et al.* (2018) [15] and Patel *et al.* (2018) [4].

3.2.1 First instar

When the larva hatches, it emerges from the egg by cutting a hole in the chorion with its mouth parts. The body of newly hatched larvae was creamy white and fed on pollen grains. The results in table-1 show that the duration of first instar larva ranged from 3 to 5 days with an average of 4.20±0.63 days. This is in close agreement with that of Nayak (2022) [10], who reported that the first instar larva ranged from 3 to 5 days with an average of 4.21±0.48. Patel *et al.* (2018) [4] recorded the average duration of first instar larva as

1.00±0.00, which is in partial conformity with the present findings.

3.2.2 Second instar
Following moulting, the second instar larvae immediately fed on fresh brinjal slices, and as they grew, they generated regular holes in brinjal slices packed with exuviae. The larva stopped eating a few minutes before it moulted. The duration of second instar larvae ranged from 4 to 5 days, with an average of 4.40±0.52 days (Table-1). This is consistent with the findings of Nayak (2022) [10], who found an average duration of 4.40±0.32, and Patel *et al.* (2018) [4], who found an average duration of 1.06±0.25, which is partially consistent with the current investigation.

3.2.3 Third instar
The third instar larva seemed quite similar to the preceding instar, but varied in size. Small brown dots formed on the body's dorsal and ventral sides, with more spots on the dorsal side; from the core of each spot came a thin spine. The third instar completion time ranged from 3 to 5 days, with an average of 4.10 ± 0.57 days (Table; 1). These findings are consistent with those of Singla et al. (2018) [15], and Patel *et al.* (2018) [4] have made the same discovery. The current study found that the average duration of the third instar larva ranged from 3 to 5 days, with an average of 4.10 ± 0.57 days. This is similar to the findings of Nayak (2022) [10], who found an average duration of 4.03 ± 0.41 days. Bhoya and Patel (2018) [4] also found an average duration of 1.73 ± 0.44 days, which is partially consistent with the present findings.

3.2.4 Fourth instar
The duration of fourth instar larva ranged from 2 to 4 days, with an average of 3.70±0.67 days (Table-1). This is consistent with the findings of Nayak (2022) [10], who recorded an average duration of 3.61±0.52, and Patel *et al.* (2018) [4], who observed an average duration of 2.66±0.47.

3.2.5 Fifth instar
At this stage, the larval instar did not appear to be as hungry as the preceding instars. The larva's shape was nearly same, with the exception that the size of different portions of the body increased proportionally, and pupating behaviour became more evident at this stage. The duration of fifth instar larvae ranged from 3 to 4 days, with an average of 3.70±0.48 days. Prior to pupation, the fifth instar larvae were lethargic and sedentary. It lost body colouration and began building the cocoon for pupation. These findings are consistent with those of Singla *et al.* (2018) [15], Bhoya and Patel (2018) [4], and Nayak (2022) [10], who reported the similar appearance of fifth instar larvae as the current study.

3.2.6 Total larval period
The analysis of the data presented in Table-1 indicates that the total larval development period of *L. orbonalis* varied between 15 and 23 days, with a mean duration of 20.10±1.20 days. These findings are consistent with those of Nayak (2022) [10], who documented a total larval development period ranging from 17 to 25 days, with an average of 20.07±1.92 days. In contrast, the studies conducted by Yadav *et al.* (2015) [18], Laichattiwar *et al.* (2017) [9], and Rohokale *et al.* (2018) [13] reported average total larval durations of 13.27, 13.20, and 15.35 days, respectively, which only partially align with the results of the current investigation.

3.3 Pupal stage
The newly developed pupa initially exhibited a pinkish hue, which transitioned to a dark brown coloration over time. It was elongated and oval in shape, tapering gradually towards the rear, with an almost straight abdomen and wing margins that extended to the posterior edge of the abdominal segment. Pupation took place on various surfaces, including glass jars, sand, muslin cloth, and within decaying fruit. The duration of the pupal stage was observed to range from 5 to 8 days, with a mean of 6.80±0.79 days (refer to Table 1). The findings of the current study align closely with those reported by Nayak (2022) [10] and Rohokale *et al.* (2018) [13], who documented average pupal periods of 6.82±0.75 and 6.90±1.37 days, respectively. In contrast, Patel *et al.* (2018) [4] and Radhakrishore *et al.* (2010) [11] reported average pupal periods of 5.76±0.77 and 5.22±0.07 days, respectively, which only partially correspond with the results of the present study.

3.4 Adult
The mature moth exhibited a white coloration, with its head and thorax adorned in greyish and brown scales. The forewings were a creamish white, featuring large, reniform patches of light brown. A subtle black wavy line was noted near the apical margin of the hindwings. Typically, the female moth was larger than the male and possessed a tuft of hairs at the tip of the abdomen. Overall, females tended to have a longer lifespan compared to their male counterparts. The lifespan of adult males ranges from 2 to 4 days, with an average of 3.67±0.58 days. In contrast, females exhibit a longevity that varies from 3 to 5 days, averaging 4.50±0.53 days (Table 1). The findings of the current study align closely with those reported by Singla *et al.* (2018) [15] and Bhoya and Patel (2018) [4], who noted similar adult characteristics as observed in this investigation. In general, females exhibited a longer lifespan than males. The longevity of male adults ranged from 2 to 4 days, with an average of 3.67±0.58 days. In contrast, female longevity varied from 3 to 5 days, averaging 4.50±0.53 days. These findings align closely with those reported by Nayak (2022) [10], who noted that male adult longevity ranged from 2 to 4 days, with an average of 3.27±0.48 days, while female longevity varied from 3 to 5 days, averaging 4.20±0.63 days. Additionally, Radhakrishore *et al.* (2010) [11] observed an average adult longevity of 5.38±0.2 for both males and females, which partially supports the results of the current investigation.

3.5 Fecundity
The egg-laying capacity observed in the laboratory during this study ranged from 170 to 248 eggs, with an average of 216.60 ± 26.68 eggs per female (Table-1). These findings align closely with those of Nayak (2022) [10], who reported an average of 219 ± 19.25 eggs per female. In contrast, Laichattiwar *et al.* (2017) [9] documented an average of 160.2 ± 32.42 eggs per female, which partially supports the results of the current investigation.

3.6 Total life cycle
The overall lifespan from the egg stage to the death of the adult ranged from 25 to 40 days, with a mean duration of

35.90±1.85 days (refer to Table 1). This finding aligns with the research conducted by Nayak (2022) [10], who also reported an average developmental period of 35.90±1.85 days. In contrast, Gosh *et al.* (2005) [6] and Yadav *et al.* (2015) [18] documented total developmental periods of 33.56±1.21 days and 25.20±0.91 days, respectively, which only partially correspond with the results of the current study.

Table 1: The length of different developmental phases, the adult stage, and the reproductive capacity of the brinjal shoot and fruit borer, *Leucinodes orbonalis*, in a controlled laboratory environment.

Biological parameters	Duration (days)	
	Range	Mean ±SD
Duration of egg stage	3-4	3.90±0.32
I-instar	3-5	4.20±0.63
II-instar	4-5	4.40±0.52
III-instar	3-5	4.10±0.57
IV-instar	2-4	3.70±0.67
V-instar	3-4	3.70±0.48
Duration of larval stage	15-23	20.10±1.20
Duration of pupal stage	5-8	6.80±0.79
Adult longevity (days)		
Male	2-4	3.67±0.58
Female	3-5	4.50±0.53
Total number of egg laid	170-248	216.60±26.68
Total life cycle	25-40	35.9±1.85

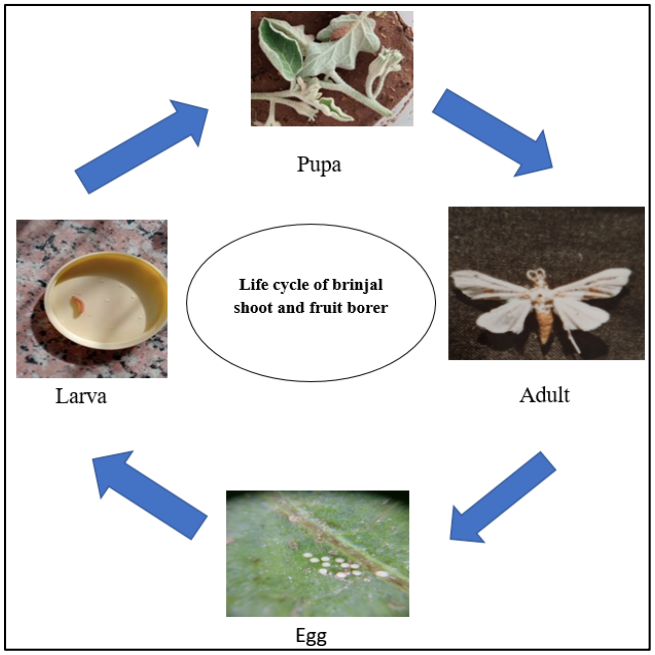

Plate 1: Life cycle of brinjal shoot and fruit borer, *Leucinodes orbonalis*

4. Conclusion

The complete life cycle of the shoot and fruit borer in brinjal was observed to last 35.9 days, based on biological research conducted during the kharif season. The average reproductive output of this pest was recorded at 216.60 eggs per female. Consequently, the environmental conditions were favorable for the growth and development of *L. orbonalis*. Therefore, it is imperative for farmers to remain particularly vigilant against this pest beginning in July and to implement BSFB control strategies in their fields. Furthermore, this study is consistent with the growth rate statistics of the pest, which can serve as a foundation for predictive measures in BSFB management.

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