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Studies on bio-ecology of shoot and capsule borer (*Conogethes punctiferalis* Guenee) on small cardamom at Malnad regions of Karnataka

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Abstract
Studies on the biology of *C. punctiferalis* revealed that the newly hatched larvae were sluggish in nature and they become active after sometime. The head was black and prominent big they were smooth skinned. The average larval duration had First, Second, Third, Fourth & Fifth instars with 3.10 ± 0.3, 2.75 ± 0.63, 2.75 ± 0.85, 3.40 ± 0.59 & 5.80 ± 0.69, respectively. While, pupal period lasted for 11.28 ± 0.88 days, respectively. Whereas, male and female had longevity was 5.50 ± 0.70 days and female longevity 8.10 ± 0.56 days. Female moth survived more than 2-3 days than the male. The average larval period ranged 17.80 ± 3.06 with 5 instars. Shoot and capsule borers, *C. punctiferalis* sexes could be easily differentiated at the pupation stage, based on the position of genital opening was found on the eight abdominal segments which was like a slit. Whereas, in male the genital opening with two raised pads found on the ninth abdominal segment. Average length and breadth of male and female pupa was15.60 ± 0.61mm, 3.39 ± 0.25mm, 17.60 ± 1.07mm and 3.39 ± 0.25mm respectively. The duration of pupal period was 9 to 11 days.

Keywords: Bio-ecology, shoot and capsule borer, cardamom, egg, pupa and adult

Introduction
Elettaria cardamomum Maton (2n = 48) is a tall (4m), herbaceous, perennial, plant with branched subterranean rhizomes, from which erect leafy shoots and erect or decumbent panicles arise. Cardamom grows well in the evergreen rain forest areas of Western Ghats of South India in altitude between 750-1500m above mean sea level (AMSL). Portuguese Barbosa mentioned cardamom as a product of the Malabar Coast (South India) in 1514 (Pusreglove, 1975) [1]. The average yield of cardamom in India is low (120 Kg/ha) as compared to that of Guatemala (250 Kg/ ha) (Charles, 1986) [2]. India is considered to be the world's largest producer and exporter of cardamom. From 1990 onwards Guatemala has emerged a leading producer and exporter (99% of global export) of cardamom. Dry capsule used for medicinal and culinary purposes. The seeds have a pleasant aroma and a characteristics slightly pungent warm in nature.

Among the various factors affecting the yield and quality of cardamom capsules, damage caused by insect pests is considered as a major constraint for its successful cultivation and pose greater threat to cardamom production in Karnataka. Out of insect pests recorded on cardamom, shoot and capsule borer, *Conogethes punctiferalis* Guenee (Lepidoptera: Crambidae) is considered to be an important pest causing damage to the cardamom suckers as well as capsules (Anonymous, 2010) [3]. The larvae bore on the panicles, spikes, flowers and capsules. The incidence of this pest coincides with flowering and fruit set in summer months. Therefore, there is a need to study in detail on cardamom shoot and capsule borer for its effective management. Hence the present investigation was carried out on biology of borer in hill zone of Karnataka.

Material and Methods
The biology of cardamom shoot and capsule borer was carried out. Temperature (maximum and minimum), relative humidity (maximum and minimum) in the laboratory were recorded during the study period.

Rearing techniques
The larvae and pupae of *C. punctiferalis* were collected from infested cardamom field and reared in laboratory (ZAHRS, Mudigere) by providing cut pieces of succulent cardamom pseudostem in Petry-dishes till pupation. The matured pupae were grouped as male and female by observing reproductive opening under binocular stereozoom microscope. The known number of pupae was kept in cage for adult emergence and the adults were reared in a cage (35cm x 30cm x 25cm) containing young cardamom cut shoots and ten per cent honey solution was provided for feeding adults. The cut ends of cardamom shoots were dipped in conical flask containing water to maintain the vigour (Fig. 1). The rearing was done under room temperature and sufficient eggs were collected from the oviposition cage and developmental stages and duration of *C. Punctiferalis* was studied.

Bio ecological studies
Egg: Eggs were observed under a stereo zoom microscope for morphological studies. Size of egg was measured using stage and ocular micrometer. The incubation period was studied by recording the date of fresh egg laid and till hatching. The observation was made at 24 hour intervals.

Determination of larval instars: The freshly emerged neonates of *C. punctiferalis* were released on cut pieces of succulent cardamom pseudostem. The sufficient cut pieces of cardamom shoots were kept in Petry' dishes for larval feeding and replaced with fresh food during every observation. The observation on larval length, width and head capsule size was done at 24 hours intervals. Dyar's law (1890) [4] was applied to distinguish the larval instars.

Pre pupa: When larva stopped feeding and became inactive to pupate, the duration between these two phases was considered as pre pupal period. The length and breadth of pre pupa was measured using a millimetre scale.

Pupa: The length and breadth of pupa was measured by using a millimetre scale. Pupal period was recorded from the date of formation of pupa to the date of emergence of the adult from the pupa. The shape and colour of pupa was also recorded.

Adult: The freshly emerged adults were processed and preserved for studying the external morphology (colour, shape and size) of moths.

Sex ratio: One hundred pupae were observed under microscope for sex determination and sex ratio. The sex was determined from the distance between genital and anal slit which was less in male pupa than that of female pupa.

Pre-oviposition, oviposition, post-oviposition and fecundity: In an oviposition cage (Plate 2) one pair of freshly emerged male and female moths were released on tender cardamom suckers. Ten such replications were maintained to study the pre- oviposition, oviposition, post-oviposition and fecundity of shoot and capsule borer. The period between emergence of the female and first egg laid is considered as pre-oviposition period. Period between first egg laid and till egg laying continued was noted as oviposition period. The period from last egg laid and till adults die is considered as post-oviposition period. Further, number of eggs laid by each female during oviposition period was recorded as fecundity.

Adult longevity: Longevity of male and female adults was determined by maintaining freshly emerged moths till their death by providing 10% honey solution as food. Observations were recorded with ten pair of moth separately.

Total life cycle: The period from freshly laid egg to till the death of adult was considered as total life cycle.

Result and Discussion
The larva of all stages of *C. punctiferalis* were found boring into tender shoots and tender capsules fed on the contents of the shoots and capsules and remained inside (Fig. 2). Neonites bored unopened leaf buds and fed on leaf tissues, they also bored the panicles leading to drying up of the portion from the affected spot. Because of feeding on the young seeds of immature capsules, the capsules became empty. Late stage larvae bored into pseudostem was observed. It fed on central core of the stem, resulting in drying of terminal leaf and produced characteristic 'dead heart' symptom. The caterpillar was light brown to pale white with brown head. Presence of larva inside the plant parts could be easily identified by frass material at the point of tunneling (Fig. 2).
The growth parameters and developmental periods of egg, larvae, pre-pupae, pupae and adult recorded were presented in Table 1 & 2. The eggs were laid singly on unopened leaves (Fig. 3).The freshly laid eggs were milky white in colour. Eggs became pinkish after 24 hours. The eggs were flat and hemispherical in shape. The tip of the egg turned to brown, when about to hatch. The egg measured 0.65 to o.76 mm, with an average of 0.75 mm. The eggs were laid singly sticking to the sides of veins and midrib of unopened leaves. The moth laid eggs both on upper and lower surfaces of tender leaves under laboratory conditions, moths were found to feed the surface of the leaf with ovipositor, move brisky on the leaf flapping the wings and then lay eggs. Oviposition was observed during night hours. Almost all eggs laid by a female were found to hatch in the laboratory. The developing larva inside could be seen through the chorion under a steriobinocular microscope. Unfertilized eggs were milky white, transparent and did not show any change in their colour but gradually shriveled. The eggs were laid individually on unopened leaves. The average incubation of egg period was 5.15 ± 0.36 days. The average length and breadth of egg measured in the laboratory was 0.66± 0.05 days and 0.41 ± 0.02 mm, respectively (Table 1). The results are in line with the work done by Bilapate and Talati (1978) [5] and Ganesh (2011) [6].
Egg hatching takes place during night hours. During its developmental period the larva moulted four times and had larval instars. The average total larval period was 17.80 ± 3.42 days. The newly hatched larvae were sluggish in nature and they became active after some time. Young larvae were translucent pale yellowish with number of short scattered hairs arising from dark coloured tubercles, which are prominent. The head was black and prominently big. They were smooth-skinned with brown prothoracic shield. The average length and breadth of first instar larva was 2.57 ± 0.08 mm and 0.40 ± 0.01mm, respectively. The average duration of first instar larva was 3.10 ± 0.30 days. As the larva advanced from first to second instar, the body grew faster and as a result the body turned wider than the head. The larva was translucent pale yellowish with a number of short scattered hairs arising from dark coloured prominent tubercles. The head was black. They were smooth-skinned

with a scattered brown colour tinge on the body which are not prominent with brown colour prothoraxic shield. The spiracles were black in colour and more prominent compared to the first instar. The average length and breadth of second instar larva 4.70 ± 0.42 mm and 0.75 ± 0.05 mm, respectively. The duration of second instar was 2.75 ± 0.63 days (Table 1).

The third instar larva was morphologically similar to that of second instar with short scattered hairs, black head, brown prothoraxic shield. The body was elongated and longer than second instar larva. The spiracles were black in colour and were nine in number. The three pairs of prothoracic legs were distinct. The crochets of the leg was black. Prolegs were present in the abdomen particularly on the sixth, seventh, eighth and ninth segmentsn. The average length and breadth of third instar larva was 9.65 ± 0.41 mm and 1.39 ± 0.15 mm, respectively. The duration of third instar 2.75± 0.85 days. The larva was comparatively stout and long with non prominent scattered hairs arising from dark coloured tubercles. The larva was pale yellowish in colour with scattered prominent brown tinge. Head and prothoraxic shield were black. Crochets on prolegs were distinct. The average length and breadth of fourth instar larva was 15.80 ± 0.78 mm and 2.48 ± 0.38 mm, respectively. The duration of fourth instar was 3.40± 0.59 days (Table 1).

Fifth instar larva was almost similar to fourth instar, except for its size. Colour of fifth instar larva was pale yellowish with a prominent scattered brown tinge and later, fully grown larva turns to translucent pale yellowish with an absence of brown tinge. Head was reddish brown. The tubercles and thoracic legs were black in colour. The spiracles were very prominent. The average length and breadth of fifth instar larva was 24.10 ± 1.19 mm and 2.90 ± 0.48 mm, respectively. The duration of fifth instar was 5.80 ± 0.69 days. Average width of second, third, fourth and fifth instars was 0.32 ± 0.01 mm, 0.51 ± 0.03 mm 0.82 ± 0.06 mm and 1.26 ± 0.06 mm, respectively. Immediately after hatching the larva was sluggish at first, later became active and bored into the unopened leaves. At the time of moulting, the larva became inactive and stops feeding. At the end of fifth instar, the larva became inactive and entered into pupation. Similar, results has shown by Bilapate and Talati (1978) [5] which had a larval duration of 17.80 ± 3.42 days. Same results observed by Gour and Sriramulu, (1992) [7].

Prepupal stage was characterized by the shortening of larva in length, suspended feeding and movement towards periphery. The colour of the larva became milky white with prominent tinge. The average length and breadth of the pre-pupa was 15.60 ± 0.84 mm and 2.82 ± 0.50 mm, respectively. The duration of prepupal stage was 3.25 ± 0.71 days (Table 1).

Pupation occurred in tunnelled shoot. The pupa was elongate and oval in shape. The eyes and the antennal case were prominent. It was light brownish in colour when freshly formed but it changed to dark brown within a few hours and got become much darker prior to emergence of moth. Abdomen was distinctly marked into ten segments with sharp dark brown spine on terminal segment. The covering of the wing was similarly prominent and was lighter than the rest of the body. Six of these spiracles were visible on either side. Female pupa was longer than male pupa in length. Pupa was obtect type with the anterior end broad, round and tapering posterior to a pointed tip. The present findings are in agreement with findings of Jacob (1981) [8], they reported similar observations on *C. punctiferalis* infesting turmeric. Gour and Sriramulu (1992) [7] reported pupal period of 8 days, while Kang *et al.* (2004) [9] reported pupal period of 9 to 11 days. Whereas close agreement with Ganesh (2011) [6], reported pupal period of 9 to 11 days.

In *C. punctiferalis* the sexes could be easily differentiated at the pupal stage based on the position of the genital opening. In case of female, genital opening was found on the eighth abdominal segment which was like a slit and it was away from anal slit. Whereas in males the genital opening with two raised pads was found on the ninth segment which was smaller and closer to anal slit. The average length and breadth of the male pupa was 15.60 ± 0.61 mm and 3.03 ± 0.13 mm, respectively, whereas the female pupa was 17.60 ± 1.07 mm and 3.39 ± 0.25 mm, respectively (Table 1). The male and female pupal period was with an average of 9.50 ± 0.51 days and 11.5 ± 1.00 days, respectively (Table 2). Similar results were found by Bilapate and Talati (1978) [5] who worked on the sex ratio of *C. punctiferalis* on castor and cardamom crops. The sex ratio showed sex ratio of 1:1 and 1:2. From the above discussion it may be inferred that the sex ratio did not change from crop to crop on which *Conogethes* fed. There are no available published reports.

In general, the adults were emerged in night time. The adults were medium sized, brownish yellow in colour with a number of dark spots on its wings. The head, thorax and abdomen were distinct. The antennae and legs were brownish yellow. Two long segmented antennae were located dorsally on the head and close to the compound eyes. The lower edges of the wings were surrounded with hair like structure and it was golden colour margins with pale veins. The adults have generally active during night hours. Male was narrower than female with brownish yellow body. The forewings were brownish yellow with thirty black dots and the hind wings were also brownish yellow with fifteen black dots.. The abdomen was sharply tapered compared to the female. The average breadth of male moth was 25.30 ± 1.20mm when wing was in extended condition and the length was 12.00 ± 0.79 mm. The average longevity of the adult male was 5.50 ±0.70 days (Table 1). The female was similar to that of male in all aspects except body size. The female was bigger with a stout abdomen that was relatively pointed in shape. The average breadth of female moth was 27.40 ± 1.55 mm when wing was in extended condition and the length was 14.80 ± 1.48mm. The average longevity of the adult female with food was 8.10 ± 0.56 days. The average total developmental period of male and female *C. punctiferalis* from egg to adult stage was 41.60 ± 3.97 days and 45.80 ± 4.08 days, respectively (Table 2) (Fig. 3). Bilapate and Talati (1978)[5] reported longevity of female and male moths to be 15.80 ±2.50 days and 14.00 ± 3.80 days, respectively. The present observations are in agreement with Jacob (1981) [8] who reported that the life cycle of *C. punctiferalis* on turmeric was 32-35 days.

Moths were observed copulating one or two days after emergence. Mating occurred during night hours. The male was very active at the time of mating and it flew several times above the female. The male gradually moved by walking close to the female with the antennae, the male touched the female. The male quickly mounts the female and soon there was a downward movement of the insect antennae. In male uncoiled proboscis during mating but returned to its original form as soon as the mating was over. The average pre-mating period was 1.15 ± 0.24 days with a range of 1 to 1.50 days and mating period ranged from 0.10 to 0.15 days with an average of 0.11 ± 0.01 days (Table 2).

The oviposition site was first located by the female. After the

site was identified, the insect cleaned the leaf surface area by using the tip of the abdomen and oviposition took place immediately. The pre-oviposition period varied from 2 to 2.50 days with an average of 2.20 ± 0.2 days, ovipositional period was 2 to 3 days with an average of 2.57 ± 0.36 days and post-oviposition period was 1.5 to 2.0 days with an average of 1.89 ± 0.18 days (Table 2).

Table 1: Biology of *Conogethes punctiferalis* L. Guenee on cardamom under laboratory conditions

Stage of insect		Duration* (days)	Length* (mm)	Breadth* (mm)	Head capsule width (mm)*
Egg		5.15 ± 0.36	0.66 ± 0.05	0.41 ± 0.02	
Larva**	First instar	3.10 ± 0.30	2.57 ± 0.08	0.40 ± 0.01	-
	Second instar	2.75 ± 0.63	4.70 ± 0.42	0.75 ± 0.05	0.32 ± 0.01
	Third instar	2.75 ± 0.85	9.65 ± 0.41	1.39 ± 0.15	0.51 ± 0.03
	Fourth instar	3.40 ± 0.59	15.80 ± 0.78	2.48 ± 0.38	0.82 ± 0.06
	Fifth instar	5.80 ± 0.69	24.10 ± 1.19	2.90 ± 0.48	1.26 ± 0.06
Total larval period		17.80 ± 3.06	-	-	-
Pre pupa		3.25 ± 0.71	15.60 ± 0.84	2.82 ± 0.50	-
Pupa	Male	9.90 ± 0.55	15.60 ± 0.61	3.03 ± 0.13	-
	Female	11.5 ± 1.00	17.60 ± 1.07	3.39 ± 0.25	-
Adult	Male	5.50 ± 0.70	12.00 ± 0.79	25.30 ± 1.20**	-
	Female	8.10 ± 0.56	14.80 ± 1.48	27.40 ± 1.55**	-
Total development period	Male	41.60 ± 3.97	-	-	-
	Female	45.80 ± 4.08			

*Number observed (N) = 20 per observation; **Breadth with wing expansion

Table 2: Pre - mating, Mating, Pre- ovipositor, Oviposition, Post oviposition period and longevity of *Conogethes punctiferalis* L. Guenee on Cardamom

Parameters	Duration (days)		
	Maximum	Minimum	Average ± SD
Pre-mating period	1.00	1.50	1.15 ± 0.24
Mating period	0.10	0.15	0.11 ± 0.01
Pre-oviposition period	2.00	2.50	2.20 ± 0.2
Oviposition period	2.00	3.00	2.57 ± 0.36
Post-oviposition period	1.50	2.00	1.89 ± 0.18
Fecundity	15.00	28.00	20.80 ±5.63

Fig 1: Methodologies followed for rearing of *C. puctiferalis*

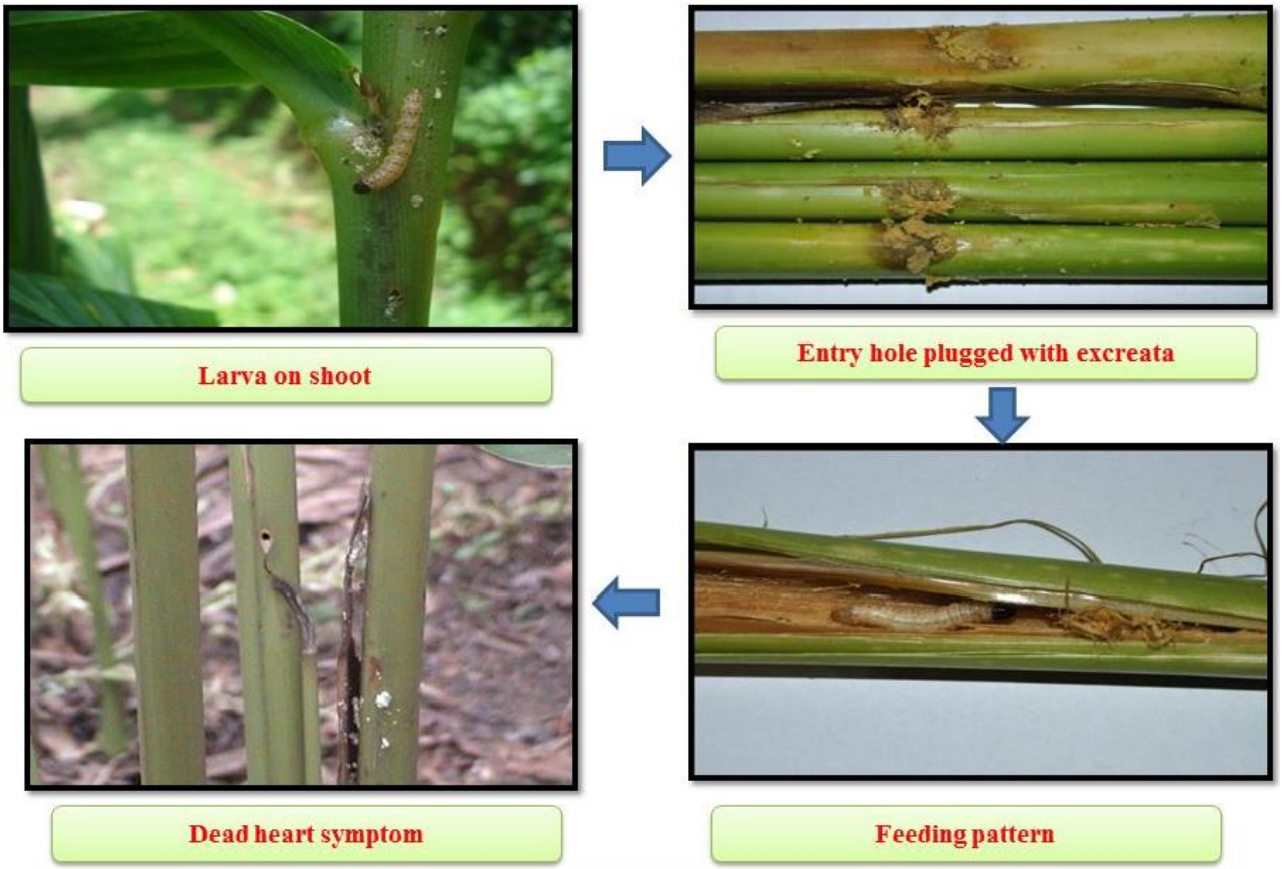

Fig 2: Shoot showing damaging symptom due to *C. punctiferalis*

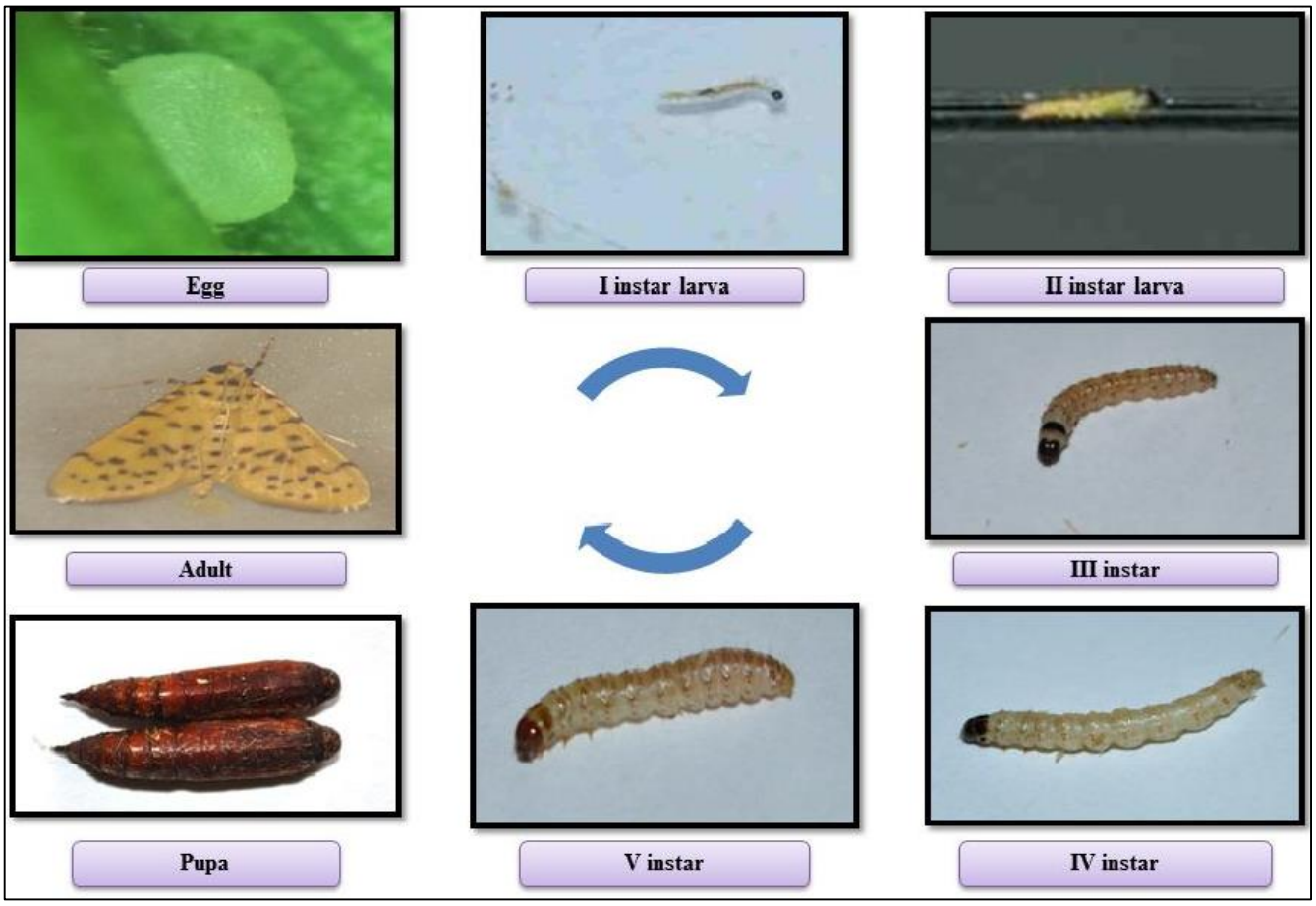

Fig 3: Life cycle of *C. punctiferalis*

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