Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(2): 3007-3010

Received: 09-01-2018
Accepted: 12-02-2018

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Life cycle of *Eocanthecona furcellata* Wolff. (Hemiptera: Pentatomidae) a predatory bug in cashew plantations, upon rearing on wax moth larvae

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Abstract
Eocanthecona furcellata Wolff. (Hemiptera: Pentatomidae) is one of the predators of pests of cashew recorded in cashew plantations in Puttur region of Karnataka. This pest predates upon soft bodied insects especially leaf feeding caterpillars including hairy caterpillars and flower damaging caterpillars. This predatory bug is commonly noticed between September and March. Biology of *E. furcellata* has been documented on different insect pests. But, this study aimed to understand the biology of *E. furcellata* on greater wax moth, *Galleria mellonella* L. (Lepidoptera: Gracillaridae) which is a common laboratory host for many insects. Incubation period of *E. furcellata* lasted for 6-7 days. There were five nymphal instars being completed in 15-19 days and cannibalism was not recorded. Female bugs were bigger and had more longevity compared to male bugs. Mean fecundity was 314 eggs. Since *E. furcellata* has shorter life cycle, higher fecundity, high survivalability; it could be mass multiplied and promoted in suitable biological pest control programmes.

Keywords: Pentatomid, *Eocanthecona*, predator, larva, wax moth, pest

1. Introduction
Cashew, *Anacardium occidentale* L. is a commercial nut crop being infested by several pests, wherein, insect management by pesticidal spray is being widely followed. Biological control is recognized as one of the best ecofriendly alternatives to the use of synthetic insecticides for controlling insect pests. Pest control with natural enemies has been increasing due to environmental, economical, social and ecological problems encountered with insecticide usage. Among the several predators, Heteropteran predators are important biological control agents on leaf worms [8], beet armyworms [5], Colorado potato beetles [17, 19], southern green stinkbugs [6] and soybean caterpillar [10]. *Eocanthecona furcellata* Wolff. (Hemiptera: Pentatomidae) is a native generalist predator that is easily reared in the laboratory and regarded as a potential larval predator. Its predation has been reported from Southeast Asia, Japan, India, and Taiwan on Lepidopteran, Coleopteran and Heteropteran insects [2, 3, 15]. Earlier, this predatory bug has been reported to be reared on larvae of *Pieris rapae* [4], frozen preserved larvae of *Spodoptera litura* [20] and *Corcyra cephalonica* [9] and its augmentative releases are recommended in Southeast Asia [16, 1]. In India, *E. furcellata* had been considered as an important predator on several important lepidopteran pests [12, 18].
In cashew ecosystems, *E. furcellata* is also one of the predators commonly noticed during October to March. These predatory bugs were noticed to predate upon a range of leaf eating caterpillars and flower pests of cashew. Attempts have been made to find its rearing feasibility on an important lab reared host, *viz.*, greater wax moth larvae and its life cycle, so that it can be used as an important biological control agent in integrated pest management programme in cashew.

2. Materials and Methods
The rearing and related observations were conducted in Entomology laboratory of ICAR-DCR, Puttur (12.45° N, 75.4° E; 90 m a.s.l.) in the Karnataka state at temperature 24-32°C; relative humidity 89-94%. The eggs and adult bugs of *E. furcellata* were collected from cashew plantations and kept separately in transparent glass bottles of 250 ml capacity covered with wet muslin cloth and maintained as stock culture.

Healthy culture of wax moth to be used as prey insects was maintained on standard diet [13]. The nymphs hatched and the adults were fed with wax moth larvae as feed. The nymphs could manage to feed on even bigger sized larvae compared to its size by pin and jab method, and even single larva was fed by 4-6 bugs at a time. To record the life cycle of this predatory bug, freshly emerged nymphs from second generation population were individually reared in glass bottles and small sized wax moth larvae were provided as prey initially. As the nymphs grow, bigger sized wax moth larvae were provided. The male and female adult bugs were paired 2-3 days after the emergence in 500 ml glass bottles, and provided with 2-3 wax moth larvae, cashew shoots and leaves. Mated females were maintained individually in glass bottles having cashew sticks and leaves to record the oviposition behaviour. The longevity of male and female bugs was also recorded. The bugs were reared in the laboratory for two generations to record its biology parameters.

3. Results and Discussion

The predatory pentatomid bug, *E. furcerllata* was noticed on shoots and panicles on cashew trees during October to March especially on young trees. Eggs were laid on the leaves and shoots and the nymphs after hatching congregated in a place under the leaf initially and later moved apart. A maximum of 8 adult bugs were noticed in a single cashew plant. These predatory bugs were noticed to predate upon a range of leaf caterpillars including hairy caterpillars (Fig. 3b) and also flower pests of cashew. However, they also fed on tea mosquito bug under confined condition in laboratory. In laboratory, the bugs readily predated upon the wax moth larvae and were active, which showed its suitability as prey.

Biological parameters of *E. furcellata* upon rearing on wax moth larvae were recorded for two generations and presented in Table 1. Incubation period lasted for 6-7 days. The egg shell had a shiny chorion with projections at the top. Freshly laid eggs were whitish in colour, later turned into creamy to light brownish. They appeared reddish before hatching, while, the hatched eggs appeared grayish (Fig. 1a-1c). Freshly emerged nymphs were reddish in colour with black patches and congregate near egg shells. As the nymphs grew, more black colour patches developed. Nymphs underwent five instars in 15-19 days and developed into adults (Table 1, Fig. 2). Nymphal survival percentage ranged from 42.9 to 83.0 among the cohorts of egg batches, and mean nymphal survival percentage was 60.7. Wind buds developed in last instar and the nymphs turned in to yellowish orange colour before moulting into adults. Cannibalism was not recorded during nymphal stages as well as adult stages when they were reared in groups of 8-10 numbers in 500 ml glass bottles along with dried cashew shoots as perch. But cannibalism was rarely observed during moulting of nymphs. Hence, these bugs are found amenable for mass rearing (Fig. 3a). Pronotal spines were seen only in adults. Female bugs lived up to a maximum of 33 days, while males lived up to 28 days. Total life cycle ranged from 45 to 54 days.

Female bugs (1.15-1.20 cm) were bigger and stouter than male bugs (0.90-0.95 cm) (Fig. 3c). The adult bugs mated after three to four days of emergence and the preoviposition period was three to four days. First batch of viable eggs was laid by the female bugs after 3-4 days of mating (Table 2). Eggs were laid individually, closely in rows arranged as a cluster (Fig.3d). A maximum of 13 such egg batches (ranged between 8-13 batches) was laid by a female with number of eggs ranging between 12 and 63/ batch and the average fecundity was 314 eggs/female under lab condition. Female bugs use their hind legs and abdomen to feel the location of other eggs before continuing deposition which may help to position the newly deposited egg as observed in *Nezara viridula* [11]. A female *E. furcellata* laid a maximum of 551 eggs in 13 batches in a period of 27 days at an ovipositional interval of 2 days (rarely 3 days) and laid eggs until a day before its death. The mean egg hatchability was 66.57 percentage (Table 2).

Variations were observed when compared to earlier studies of the biology of *E. furcellata* on lepidopteran larvae *Prodenia litura* F [7], *Spilarctia oblique* Walk. [18], *Maruca vitrata* [14] and *Corcyra cephalonica* [9]. For eg., on *Maruca vitrata*, total nymphal period of *E. furcellata* was about 15-18 days and male and female longevity were 12.5 to 15.5 days and 21 to 24 days, respectively [14]. This could be due to the variation in prey insects besides geographical situations and weather parameters.

Table 1: Life cycle parameters of *E. furcellata* in laboratory conditions

Particulars	Duration in days (mean ± SE)	
	Generation I	Generation II
Incubation period (x = 180)	6.36±0.48	6.37±0.48
Stadial period (x = 100)		
I	2.85±0.37	2.69±0.47
II	2.99±0.40	2.87±0.43
III	2.54±0.51	2.62±0.10
IV	2.96±0.66	3.35±0.49
V	5.12±0.67	4.62±0.75
Nymphal period	15.65±1.41	16.04±1.11
Total developmental period	22.25±1.49	22.58±1.30
Nymphal survival (%)	62.41±15.65	59.13±16.23
Adult longevity (x = 10 each)		
Male	23.80±3.30	22.56±2.24
Female	28.12±2.91	28.54±2.98

Table 2: Ovipositional parameters of *E. furcellata* (X=7)

Particulars	Mean ± SE	Range
Period of sexual maturity (days)	3.13± 0.34	3-4
Preoviposition period (days)	3.20±0.41	3-4
Oviposition period (days)	22.88±2.68	19-27
Fecundity (No. of eggs)	314.38±98.87	216-551
No. of egg batches laid/female	9.13±1.20	8-13
No. of eggs/batch	35.69±11.29	12-63
Hatchability (%)	66.57 ±15.64	36-98

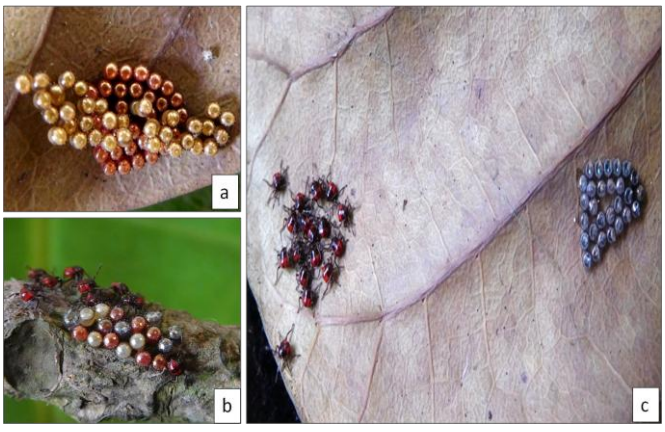

Fig 1: *E. furcellata* a. eggs – reddish ones are ready to hatch b. hatched eggs (grey) and just emerged nymphs c. congregation of nymphs after hatching

Fig 2: Developmental stages of *E. furcellata*. a. first instar nymph predating on a wax moth, b. moulting of 1st instar nymphs, c. 2nd instar nymphs, d. 3rd instar nymphs, e and f. later instars

Fig 3: a. Group feeding of wax moth larvae by *E. furcellata* adults in lab, b. *E. furcellata* predating a common defoliating hairy caterpillar on a cashew tree in field, c. a mating pair of *E. furcellata*, in which, female bug is predating on a wax moth larva, d. oviposition by the female bug.

4. Conclusion

The present study shows that wax moth larvae can be very well used as prey insects for successful mass rearing of *Eucanthecona furcellata*. The characters like shorter life cycle, higher fecundity, high survival and feasibility of group rearing of *E. furcellata* are the favourable features for biological control agents especially predators, hence, these predatory bugs could be promoted for suitable biological control programmes of leaf and flower feeding caterpillars of cashew and could be integrated in possible IPM programmes.

5. Acknowledgement

Authors express their gratitude to Dr. V.V. Ramamoorthy, NPIB, IARI, New Delhi for identifying the species. Authors also thank the Director, ICAR-DCR for the facilities provided.

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