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Studies on the biology of three coccinellid predators on pink hibiscus mealy bug *Maconellicoccus hirsutus* (Green) in Odisha

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Abstract
Laboratory experiment was conducted to study the biology of coccinelid predators of Odisha. About 17species of predatory coccinellids were identified from different crops; the most important being *Coccinella septempunctata, Coccinella transversalis* and *Cheilomenes sexmaculata, Cryptolaemus montruzeiri, Brumoides suturalis* and *Scymnus coccivora* in aphid and mealy bugs infested plants. The biological parameters indicated that *C. montruzeiri* was the largest and *S. coccivora* was the smallest among the Coccidophagous coccinellids. The grubs of all the predatory coccinellids were found to be most susceptible to the rising temperatures. Therefore, it was observed that total developmental period was highest in the month of November and lowest in the month of May for all species. Total larval period was 22.0±0.08 20.1±0.09 and 13.9±0.13 days in November and 9.2±0.11, 9.10±0.04 and 10.9±0.63 in the month of May in respect of *C. montruzeiri, B. suturalis* and *S. coccivora* respectively. The total developmental periods in respect of the three species were 27.3±0.64, 25.2±0.11 and 17.1±0.09 days in the month of November and 11.7±0.64, 10.4±0.64 and 12.3±0.61 days in the month of May respectively. Pre pupae and pupae were least affected by the fluctuation of temperature.

Keywords: *Cryptolaemus montruzeiri*, *Brumoides suturalis*, *Scymnus coccivora*, life stages, size, duration, mortality, morphometrics, relative abundance

Introduction
Biological control is relatively permanent, safe, economical and eco – friendly way of pest management. It can be defined as the action of parasitoids, predators and pathogens in maintaining other organisims density at lower average than would occur in their absence. The safety of biological control is outstanding because many natural enemies are host specific or restricted to few closely related species. The family Coccinellidae comprises of more than 6,000 species (Marin *et al.*, 2010) [9] of ladybirds and includes the predacious beetles of economically important insect pests such as aphids, thrips, mites and whiteflies (Gupta *et al.*, 2012; Hodek and Honek, 1996) [5, 6]. One of the potential predacious ladybird, *Coccinella septempunctata* Linnaeus (Coleoptera: Coccinellidae), originally native to Palearctic region but now been prevalent in most parts of the world has been exploited as biocontrol agent in various control programs (Honek and Martinkova, 2005) [7] due to its feeding aggressiveness as well as high biotic potential and voracity (Shannag and Obeidat, 2008) [12]. As coccinellids are very important natural enemies of various agricultural pest it is very important to know their diversity with some of scientific evidence including morphometrics speciations so that they ultimately helps in proper identification of these important predator species.

Material and Methods
In order to assess the relative abundance of various species of predaceous coccinellids in Bhubaneswar locality, a regular field survey of different crop fields in Central Research Station, OUAT, Bhubaneswar was undertaken from September, 2015 to March, 2016 (Table. 1). The lady birds were reared in the laboratory for maintaining uninterrupted supply of different life stages throughout the period of study. Adults of different species of ladybirds, *viz.*, three coccidophagous species i.e. *Cryptolaemus montruzeiri* (Mulsant), *Scymnus coccivora* (Ayyar) and *Brumoides suturalis* (Fabricius) were found in different crops like okra, mustard, cabbage, greengram, cowpea and groundnut were the predominant species around Bhubaneswar locality. The coccidophagous lady bird *viz*; *Cryptolaemus montrouzieri, Scymnus coccivora* and *Brumoides suturalis* were recorded on mealy bug, *Maconellicoccus*

hirsutus grown on ripe pumpkins. Ripe pumpkins were obtained from market with no wounds and having ridges and furrows. They were cleaned with 0.1% formalin and then with tap water, dried under shed and placed in cages of 1'X1'X1' with cotton walls. The culture of mealy bug *M hirsutus* was placed near the stalk of the pumkin and kept in racks. In about 20 days the pumpkins were fully covered by the mealy bugs and were used for the rearing of coccidophagous lady birds. The mealybug was also reared on sprouted potato for providing counted number of mealybugs to the predatory beetles. The required potatoes were brought from market and washed under tap water to remove the dirt on the tubers. The tubers were sterilized with bavistin @2g/lit of water for 10 minutes and washed with tap water and kept it for drying. The trays were filled with sterilized soil evenly and potatoes were placed on soil by exposing the eyes for sprouting. The trays were covered with black cloth for early sprouting of the tubers. The tubers were kept at room temperature and watering was done on every day. At one inch sprouting stage or at one week after sprouting 2-3 gravid females were released. The mealybug culture was developed fully after 10-12 days, which was used for further studies. Five pairs of adult beetles of each species *viz*; *Cryptolaemus montrouzieri*, *Brumoides suturalis* and *Scymnus coccivora* and were realesed inside the cages containing *M. hirsutus* on ripe pumpkin for feeding on the mealy bugs. The lady birds prayed upon the mealy bug nymphs and adults and laid eggs near the mealy bug colonies. Ten freshly laid eggs of each species were separated out and kept in petridishes (10 cm x 1.5 cm) for hatching and further rearing. Three replications were maintained for each species. The early instar grubs were provided with early instar nymphs of *M. hirsutus* on sprouted potato. Each grub was provided with sufficient number of mealy bugs every 24 hours, after removing it to a new petridish, so that there was no dearth of food. Observations were recorded on the duration of different instars. This procedure was followed till the lady bird grubs pupated. Developmental period of different stages and measurement of egg and larval instars were recorded. Ten prepupa of each species were separated out and kept in petridishes. Three replications were maintained. Prepupal and pupal periods of each species and their measurements were recorded. Ten freshly emerged adult mating pairs of each species were removed from the stock culture and were reared individually in petridishes on *M. hirsutus*. Eggs laid every day was calculated. This was also replicated 3 times. Observations on fecundity, longevity of females and male coccinellid beetles and their measurements were also recorded. The biology of all the species of lady birds was studied during the months of January, March, May, July, September and November during 2015 pertaining to different climatic regimes of the year. In case of natural death of any individual in the experimental stages, the same was replaced with an individual of the same age simultaneously maintained in the stock culture of lady birds. Observations on morphometrics of life stages of different predatory coccidophagous coccinellids were also recorded. Data, thus obtained were statistically analysed by descriptive method as suggested by Gomez and Gomez, (1984) [4].

Results and Discussion

Among the three coccidophagous coccinellid beetles, *Cryptolaemus montrozeuiri Scymnus coccivora* and *Brumoides suturalis* the life stages of *C. montrozeuiri* were the largest as revealed from the measurements of egg and different other life stages in table 2. The eggs were oval to cylindrical in shape having a smooth round end, 1.1±0.12 mm long and 0.3±0.00 mm broad, yellowish white in colour with shiny and smooth surface. The eggs were yellow with a trace of orange shading and cigar shaped with rounded end. The length and breath of the eggs were 1.02+0.01 and 0.42±0.05 respectively for *Brumoides suturalis* and for *Scymnus coccivora* the eggs were 1±0.00 mm long and 0.33±0.04 mm broad respectively. Similarly all the larval stages of *C. montrozeuiri* measured about 1.5±0.01, 2.4+0.08, 4.3+0.11, 4.8+0.31mm and 0.3+0.01, 0.6+0.01, 1.5+0.13, 2.2+0.19mm respectively. The body measurements of first, second, third and fourth instar grubs were recorded as 2.1+0.00, 3.1+0.01, 4.5+0.01, 4.3+0.06 mm in length and 0.7+0.01, 1.02+0.03, 1.3+0.14, 2.2+0.08 mm in breadth respectively for *B. suturalis*. The fourth instar grubs of *S. coccivora* were oval, flat and depressed slightly at the middle with broad prothorax measuring about 4.9±0.05 mm long and 1.5±0.01 mm broad respectively. Similarly the pupae of *C. montrozeuiri* measured about 4.3±0.33 mm in length and 3.1±0.34 mm in breadth as compared to 4.1±0.32 mm in length and 3.31±0.08 mm in breadth *B. suturalis* and 2.5±0.5 mm in length and 2.01±0.1 mm in breadth of *S. coccivora.* Adult male of *C. montrozeuiri* were 4.4±0.58 in length and 4.3±0.32 in breadth. *B. suturalis* male were 3.9±0.29 mm in length and 3.5±0.00 mm in breadth. The measurements for *S. coccivora* male were 3.2±0.5 mm in length and 2.9±0.4 mm in breadth. The female of *C. montrozeuiri* measured about 4.9±0.11 mm in length and 4.1±0.61 mm in breadth where as the measurements for *B. suturalis* were 4.6±0.13 mm in length and 4.2±0.14 mm in breath and that of *S. coccivora* were 3.3±0.6 mm in length and 3.0±0.1 mm in breadth respectively. Ullah *et al.*, (2012) had similar observations on the morphometrics of *B. suturalis*, *C. montrozeuiri* and *M. sexmaculata* at Pakistan. Observations in the present investigations are in conformity with the findings of Murthy (1982) [10]; by Mani (1986) [8]; Baskaran *et al.* (1999) [1] and Naik *et al.* (2003) [11].

Seasonal variations: Duration of life stages of the predatory coccinellids were studied during different months of the year, *i.e.*, in January, March, May, July, September and November representing different environmental conditions of the year, the corresponding temperatures being 21.7, 28.5, 37.2, 30.1,28.1 and 27.6^{0}C in table 3. Among the coccidophagous coccinellids, *C. montrouzieri* had the longest developmental period during all these months followed by *B. suturalis* and *S. coccivora*. As in case of the aphidophagous coccinellids, it was observed that during the cooler months, the life stages are longer and in the warmer months, the life stages are shorter for all the coccinellids. In the month of January (Mean temperature 21.7^{O}C) the total developmental period, *i.e.*, from egg to adult stage, took 26.4±0.14 days in *C. montrouzieri*, whereas, it took 21.9±0.17 and 19.2±0.13 days in case of *B. suturalis* and *S. coccivora* respectively. When temperature increased in May (Mean temperature 32.7^{O}C) the total developmental periods were 11.7±0.64days, 11.1±0.04 days and 10.4±0.11 days respectively for the three species. Again when temperature increased in September, the total developmental periods increased to 24.7±0.64 days, 21.2±0.41 days and 20.5±0.03 days for the three coccidophagous species. The fecundity of different species indicated the same trend, more eggs being laid in cooler months of November and January and less eggs being laid in

warmer months. It was also observed that *C. montrouzieri* laid more eggs than the other two species Similarly, more eggs were viable in the cooler months than in the warmer months and more percentage of eggs of *C. montrouzieri* were viable as compared to *B. suturalis* and *S. coccivora*. The adult beetles also lived for more days in cooler months than in warmer months. Our findings are in agreement with the findings of Fand *et al*., (2010) [3] and Shindhe *et al*., (2016) [13] had similar observations on the biology of *C. montrouzieri* while Chakraborti and Korat (2013) [2] had the similar observation on the biology of *B. suturalis.*

Table 1: Survey of predaceous coccinellids in Bhubaneswar

Crop	Month	*Adult population per 10 plants				
		C. septempunctata	*C. transversalis*	*C. sexmaculata*	*B. suturalis*	*S. coccivora*
Okra	Feb.	1.6	0.6	0.3	1.3	0.3
	Mar.	1.2	0.8	0.7	0.4	0.1
	April	1.3	0.9	0.8	0.3	0.4
	May	0.4	0.1	0.3	1.2	0.8
	June	1.0	0.3	0.7	0.5	0.7
	July	1.3	0.2	0.9	0.6	1.0
	Aug.	1.5	1.3	1.1	0.7	0.9
Green gram	Sept.	2.4	1.3	2.9	1.6	0.9
	Oct.	2.2	2.5	1.9	1.8	1.3
	Nov.	2.3	1.8	2.2	0.3	0.2
	Dec.	0.3	1.7	1.6	1.0	0.9
	Jan.	1.5	1.3	1.2	1.8	0.7
	Feb.	1.2	0.9	2.5	1.9	0.4
	Mar.	1.7	0.7	2.7	0.2	1.3
Cowpea	Sept.	2.2	1.5	1.2	1.0	0.7
	Oct.	1.3	1.2	1.1	0.8	0.4
	Nov.	1.7	1.1	0.7	0.5	0.3
	Dec.	1.8	0.9	0.5	0.9	0.6
Groundnut	Sept.	1.4	1.7	0.7	0.3	0.8
	Oct.	1.3	1.5	1.3	0.4	0.3
	Nov.	1.9	1.2	1.1	0.7	0.5
	Dec.	1.7	1.1	0.8	0.5	0.9
	Jan.	1.2	1.8	0.9	1.1	0.6
	Feb.	1.0	1.4	1.1	1.0	1.2
	Mar.	1.1	1.2	0.7	1.2	0.7
Mustard	Nov.	2.3	2.1	2.0	0.8	0.9
	Dec.	3.1	2.7	1.7	1.6	2.0
	Jan.	4.8	2.2	1.2	0.5	1.3
	Feb.	3.2	1.6	0.6	0.2	0.3
	Mar.	3.9	2.3	1.3	0.0	0.8
Cabbage	Dec.	5.0	3.6	2.0	1.3	1.5
	Jan.	4.3	4.2	2.7	1.5	1.3
	Feb.	3.3	2.3	2.1	0.9	2.1
	Mar.	2.7	1.9	1.6	1.3	0.8

Table 2: Measurements of life stages of coccidophagous coccinellids

Developmental stages	*Measurements (mm) (Mean ± S.E.)					
	C. montrouzieri		*B. suturalis*		*S. coccivora*	
	Length	Breadth	Length	Breadth	Length	Breadth
Egg	1.1±0.12	0.3±0.00	1.02±0.01	0.4±0.05	1.0±0.00	0.3±0.04
I instar grub	1.5±0.01	0.3±0.01	2.1±0.00	0.72±0.01	1.2±0.04	0.6±0.01
II instar grub	2.4±0.08	0.6±0.01	3.1±0.01	1.02±0.03	2.1±0.03	0.7±0.03
III instar grub	4.3±0.11	1.5±0.13	4.5±0.01	1.34±0.14	3.0±0.11	1.4±0.04
IV instar grub	4.8±0.31	2.2±0.19	4.3±0.06	2.2±0.08	4.9±0.05	1.5±0.01
Pupa	4.3±0.33	3.1±0.34	4.1±0.32	3.3±0.08	2.5±0.5	2.01±0.1
Adult male	4.4±0.58	4.3±0.32	3.9±0.29	3.5±0.00	3.2±0.5	2.9±0.4
Adult female	4.9±0.11	4.1±0.61	4.6±0.13	4.2±0.14	3.3±0.6	3.0±0.1

*Mean of ten replications

Table 3: Duration of life stages of *C. montrouzieri*, *B. suturalis and S. coccivora* on *M. hirsutus* (2015)

Stages of development	*C. montrouzieri*						*B. suturalis*						*S. coccivora*					
	*Developmental period in days (Mean±S.E.)						*Developmental period in days (Mean±S.E.)						*Developmental period in days (Mean±S.E.)					
	January	March	May	July	September	November	January	March	May	July	September	November	January	March	May	July	September	November
Egg	4.7±0.09	2.3±0.13	1.1±0.11	2.3±0.14	3.1±0.01	3.7±0.17	3.2±0.37	2.1±0.14	1.0±0.31	1.9±0.64	2.7±0.16	2.9±0.18	4.6±0.61	3.9±0.09	3.0±0.00	4.1±0.16	3.7±0.06	4.2±0.51
Grub																		
I instar	3.7±0.17	2.6±0.14	2.5±0.12	3.7±0.01	5.7±0.36	5.9±0.11	2.4±0.62	2.0±0.00	2.3±0.01	1.9±0.06	3.4±0.61	4.8±0.41	2.7±0.13	2.1±0.06	2.1±0.36	3.8±0.14	2.9±0.04	3.9±0.23
II instar	3.6±0.67	2.2±0.01	2.2±0.14	2.9±0.61	3.8±0.58	4.8±0.19	3.7±0.06	2.0±0.00	2.6±0.04	2.8±0.13	3.6±0.13	3.7±0.09	3.5±0.43	2.9±0.64	2.9±0.11	3.7±0.17	2.7±0.17	3.6±0.39
III instar	2.4±0.06	2.6±0.17	2.7±0.67	2.8±0.11	4.9±0.54	5.7±0.71	3.6±0.01	3.1±0.07	2.1±0.01	3.8±0.17	3.9±0.01	4.9±0.03	3.7±0.39	3.7±0.11	3.6±0.05	3.2±0.36	2.8±0.13	3.5±0.23
IV instar	3.8±0.14	2.8±0.72	2.4±0.19	3.6±0.09	4.8±0.16	4.8±0.11	4.8±0.31	3.6±0.03	2.6±0.03	3.3±0.11	4.8±0.03	4.6±0.00	3.9±0.32	3.2±0.03	2.5±0.03	3.5±0.07	3.1±0.01	3.7±0.01
Total larval period	15.2±0.08	10.7±0.61	9.2±0.11	14.4±0.61	20.8±0.92	22.0±0.08	14.6±0.62	10.6±0.31	9.1±0.04	12.5±0.02	17.8±0.64	20.1±0.09	14.2±0.13	12.9±0.46	10.9±0.63	13.2±0.13	12.7±0.03	13.9±0.13
Prepupa	1.3±0.01	1.0±0.00	1.0±0.00	1.0±0.00	1.1±0.01	1.2±0.01	2.7±0.13	1.0±0.00	1.2±0.31	3.6±0.39	2.1±0.18	2.4±0.11	1.2±0.02	1.0±0.00	2.0±0.00	1.0±0.00	1.0±0.00	1.2±0.01
Pupa	5.8±0.07	3.1±0.03	2.0±0.08	2.8±0.61	2.1±0.01	3.4±0.06	3.4±0.17	1.1±0.11	1.3±0.11	3.8±0.19	3.1±0.14	2.2±0.14	1.2±0.13	1.8±0.61	1.7±0.06	1.5±0.17	2.9±0.09	2.1±0.39
Total Development	26.4±0.14	15.7±0.63	11.7±0.64	17.2±0.32	24.7±0.64	27.3±0.64	21.9±0.17	11.7±0.06	10.4±0.64	23.8±0.16	24.7±0.64	25.2±0.11	17.2±0.13	16.7±0.06	15.4±0.11	16.9±0.13	16.5±0.03	17.1±0.09
Adult male	22.8±0.81	20.9±2.42	17.6±0.31	21.7±3.62	20.1±1.32	22.0±0.00	20.4±3.21	19.3±0.38	15.7±0.13	18.7±0.46	19.7±0.43	20.1±0.98	22.8±1.37	/20.9±2.42	17.6±0.31	21.7±3.62	20.1±1.32	22.0±0.00
Adult female	34.8±0.81	26.4±0.93	22.0±0.13	29.1±0.14	33.9±0.64	34.2±0.49	23.7±0.94	33.2±0.17	19.8±0.09	28.3±3.46	22.2±0.61	22.9±0.41	32.2±2.43	22.0±0.00	20.7±2.64	25.0±0.00	25.8±0.78	30.1±1.19

Conclusion

The results of the laboratory experiments revealed that the predominant coccidophagous predatory coccinellids are *Scymnus coccivora* and *Brumoides suturalis.* These beetles were present in all the crops surveyed feeding on aphids and mealy bugs. Among the coccidophagous ones, *C. montrouzieri* has all the attributes as that of *C. septempunctata*. Aphids and mealy bugs increased build up in various species of crop plants and in the wild mainly due to certain abiotic changes in climate and environment. These pests can be effectively managed by the predatory coccinellids. These beetles, along with some less toxic insecticides can form a formidable IPM package for management of sucking pests of crops.

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