Journal of Biological Control, 24 (1): 35–41, 2010

Research Article

Comparative biology of four coccinellid predators of solenopsis mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae)

BABASAHEB B. FAND[1*], R. D. GAUTAM[1] and SACHIN S. SUROSHE[2]

[1]*Biological Control Laboratory, Division of Entomology, Indian Agricultural Research Institute, New Delhi 110012, India.*

[2]*National Research Center on Pomegranate (ICAR), Solapur, Maharashtra, India.*

[*]*Corresponding author E-mail*: babasaheb_ento@rediffmail.com

ABSTRACT: The biology of four important species of coccinellid predators, *viz*., *Hyperaspis maindroni*, *Cryptolaemus montrouzieri*, *Nephus regularis* and *Scymnus coccivora* associated with solenopsis mealybug, *Phenacoccus solenopsis,* infesting cotton and other crops of economic importance was studied in the laboratory @ 27±2°C and 65±5% RH. The overall developmental time (including adult longevity) of *C. montrouzieri* was found significantly longer (97.80±1.32 days) than the rest of the species which ranged between 58.60±2.38 and 72.40±2.11 days. Females generally had longer developmental durations than males, irrespective of the species. The females of *C. montrouzieri* laid an average of 510.00±9.73 eggs in their oviposition period of 62.20±3.14 and this was longer than the others. In all the species, female started egg laying in the 2nd week of their adult life and reached the peak between 3rd and 6th weeks.

KEY WORDS: *Hyperaspis maindroni, Cryptolaemus montrouzieri,* developmental durations, longevity, *Nephus regularis, Phenacoccus solenopsis, Scymnus coccivora*

(Article chronicle – Received: 24.12.2009; Sent for revision: 05.01.2010; Accepted: 02.02.2010)

INTRODUCTION

Recently in India, cotton crop in Delhi, Gujarat, Haryana, Maharashtra, Punjab and Rajasthan was seriously infested with the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) (Dhawan *et al*., 2007; Gautam *et al*., 2007; Jhala *et al*., 2008). During 2007, *P. solenopsis* spread to major cotton growing belts of Punjab and caused 30-40% yield loss in cotton (Dhawan *et al.,* 2007). The mealybug has spread throughout the country (Tanwar *et al*., 2007; Jhala *et al*., 2008) and warrants search for suitable biocontrol agents for bio-intensive management of mealybugs in India.

Interestingly, a good number of natural enemies comprising ladybird beetles, *viz., Hyperaspis maindroni* Sicard [earlier reported as *Brumoides lineatus* (Weise), Gautam *et al*., 2007]*, B. suturalis* (Fabricius) (Tanwar *et al*., 2007; NCIPM, 2008)*, Cheilomenes sexmaculata* (Fabricius), *Coccinella septempunctata* Linnaeus, *Nephus regularis* Sicard and *Scymnus coccivora* Ayyar; green lacewings, *Chrysoperla* sp. (*carnea*-group) and *Mallada desjardinsi* (Navas) [= *M. boninensis* (Okamoto)] were found as natural regulating agents on *P. solenopsis*. *H. maindroni* is a potent natural enemy of coccids and aphids from the Indian sub-region (Poorani, 2004). As the predatory beetles have been reported to exercise a good deal of natural control on the mealybug, the life history parameters of four important coccinellid species, *viz., H. maindroni*, *Cryptolaemus montrouzieri* Mulsant, *N. regularis* and *S. coccivora* on *P. solenopsis* reared on sprouted potato tubers were studied under laboratory conditions.

MATERIALS AND METHODS

The experiment was carried out in the Biological Control Laboratory, Division of Entomology, Indian Agricultural Research Institute, New Delhi during 2008-09. The cultures of the mealybug and coccinellid predators were maintained in the laboratory as suggested by Gautam (2008).

Rearing of host insect, P. solenopsis

The mealybug culture was maintained in the laboratory on sprouted potato tubers as per Gautam (2008). About 5-6 medium sized sprouted potato tubers were

kept in a jar of 10 cm diameter. Newly emerged crawlers or 2-3 gravid females were released on the potato sprouts with the help of a camel hairbrush. The jars were covered with a clean black muslin cloth and tied with a rubber band. The jars were kept at 27 ± 2°C and 65 ± 5% RH. The mealybug culture was developed fully after 10-12 days, which was used for further studies.

Rearing of coccinellid predators

The nucleus cultures of the coccinellid predators, *viz., H. maindroni, C. montrouzieri, S. coccivora* and *N. regularis* were maintained on mealybug infested sprouted potato tubers in the laboratory by following Gautam (2008). Five pairs of the predators released in a jar containing sprouted potatoes infested with the mealybug. The jars were covered with a clean black muslin cloth and tied with a rubber band and were maintained at 27 ± °C and 65 ± 5% RH.

Developmental periods of immature stages

The eggs laid on the potato sprouts, tissue papers placed at the bottom of the rearing jars and the walls of the jars were gently separated with camel hairbrush and kept in small vials till hatching. The period between egg laying and hatching was considered as incubation period. Newly hatched grubs kept individually in small glass vials (5 x 1.5 cm) were provided sufficient food throughout their developmental period. The food was changed daily, offering mealybugs in excess of that eaten on the previous day. Each vial was carefully observed twice a day to know whether the larvae had moulted in order to record the duration of each instar, the summation of each of which gave the total larval period. Additionally, the pupal periods and the developmental time (egg to adult) were recorded for every species (Chandrababu *et al.*, 1999).

Preoviposition, oviposition, fecundity and longevity of adults

Newly emerged adults were fed with honey (20%). The beetles were randomly paired and kept in small vials (10 x 2.5cm) with prey. To study preoviposition, oviposition and postoviposition periods, adult longevity, and number of eggs laid per female per day the beetles were observed daily until they died (Chandrababu *et al.*, 1999).

Statistical analysis

The data obtained from replicated trials on the parameters under consideration were subjected to one-way analysis of variance in SPSS statistical programme (version 13.0). The critical difference (P) was worked out where variance ratio was found significant for treatment effect. The treatment effects were tested at 5% probability level for their significance. The means were separated by least significant square (LSD) test at P ≤ 0.05%.

RESULTS AND DISCUSSION

The results revealed that the developmental period of the predatory beetles varied significantly between the species when reared on *P. solenopsis* in laboratory. Developmental times for eggs, larvae and pupae of the four coccinellid predators at 27 ± 2°C and 65 ± 5% RH are presented in Table 1. Eggs of *C. montrouzieri* had the maximum incubation period with significant differences (P ≤ 0.05%). The total developmental periods of immature stages of *H. maindroni* and *C. montrouzieri* were on par with each other, but statistically significant from *N. regularis* and *S. coccivora*, both being on par. It was seen that the grubs of all the four species underwent moulting three times with four instars in their life cycle. Comparatively, grub and pupal periods of *H. maindroni* were more than the other species of coccinellids studied. However, overall life period (including adult longevity) was longer for *C. montrouzieri*. In general, females took longer to develop than males of each species. Newly hatched grubs were devoid of wax coating and were purple (*H. maindroni*) or pale yellowish (*C. montrouzieri, N. regularis* and *S. coccivora*). The grubs of *C. montrouzieri, N. regularis* and *S. coccivora* developed a white wax coating and wax filaments on their body within 24 h of eclosion, whereas it was absent from that of *H. maindroni* (Plates 1b, 2b, 3b and 4b). The durations of each larval instar are given in Table 1. After feeding ceased, mature grubs became sluggish and started congregating for pupation on the undersurface of the tissue paper placed at the bottom of the rearing jar. *H. maindroni* recorded the longest pupal period whereas pupal duration of *S. coccivora* was found to be the shortest.

Newly emerged adult beetles mated after 2.0 to 3.0 days and most of the pairs mated frequently for 4-5 times in a day. The durations of mean preoviposition (6.8 ± 0.37 days), oviposition (62.20 ± 3.14 days) and postoviposition (28.80 ± 2.69 days) were longest for *C. montrouzieri* (Table 2). Adult longevity was significantly higher in females than in males in all the species. Average daily oviposition ranged between 3.4 ± 0.51 and 9.4 ± 0.93 eggs / female (Table 3). The mean fecundity of *N. regularis* was the lowest among all (148.80 ± 3.85 eggs / female). In all the four species, female started egg laying in the 2nd week of their adult life and reached the peak between 3rd and 6th weeks (Fig. 1). The egg laying continued up to 8th week in *H. maindroni, N. regularis* and *S. coccivora,* whereas in case of *C. montrouzieri* it ceased after 11th week. The females survived on an average more than a week after their reproductive period was over.

Table 1. Developmental durations of immature stages of coccinellid predators reared on *P. solenopsis*

Predator species	Mean developmental duration (Days) ± SE						
	Egg	Larval instars				Pupa	Egg to Adult
		L1	L2	L3	L4		
H. maindroni	4.9 ± 0.10[a]	4.4 ± 0.19[a]	3.3 ± 0.20[a]	3.5 ± 0.16[a]	4.1 ± 0.10[a]	11.8 ± 0.37[a]	32.0 ± 0.45[a]
C. montrouzieri	5.5 ± 0.22[b]	4.4 ± 0.19[a]	3.0 ± 0.00[a]	3.2 ± 0.12[a]	4.2 ± 0.12[a]	10.8 ± 0.49[bc]	31.1 ± 0.60[a]
N. regularis	4.7 ± 0.20[a]	3.2 ± 0.12[b]	2.1 ± 0.10[b]	2.3 ± 0.20[b]	3.3 ± 0.12[b]	9.8 ± 0.37[c]	25.4 ± 0.40[b]
S. coccivora	4.5 ± 0.22[a]	2.1 ± 0.19[c]	1.8 ± 0.12[b]	1.7 ± 0.12[c]	3.1 ± 0.19[b]	8.5 ± 0.22[d]	21.7 ± 0.20[c]
CD (P ≤ 0.05%)	0.58	0.52	0.38	0.46	0.41	1.13	1.30

*Within columns means followed by different letters are statistically significant (LSD, P ≤ 0.05%)

Table 2. Preoviposition, oviposition, and postoviposition periods and longevity of coccinellid predators reared on *P. solenopsis*

Predator species	Duration in days (± SE)			Longevity in days (± SE)	
	Preoviposition	Oviposition	Postoviposition	Female	Male
H. maindroni	5.40 ± 0.51[a]	47.80 ± 2.42[a]	19.20 ± 1.16[a]	72.40 ± 2.11[a]	60.00 ± 2.76[a]
C. montrouzieri	6.80 ± 0.37[b]	62.20 ± 3.14[b]	28.80 ± 2.69[b]	97.80 ± 1.32[b]	86.60 ± 1.72[b]
N. regularis	4.40 ± 0.40[a]	38.60 ± 2.54[c]	15.60 ± 68[a]	58.60 ± 2.38[c]	47.60 ± 1.29[c]
S. coccivora	4.60 ± 0.24[a]	39.80 ± 1.39[c]	15.40 ± 0.81[a]	59.80 ± 1.46[c]	48.60 ± 0.927[c]
CD (P ≤ 0.05%)	1.18	7.36	4.66	5.61	5.43

*Within columns means followed by different letters are statistically significant (LSD, P ≤ 0.05%)

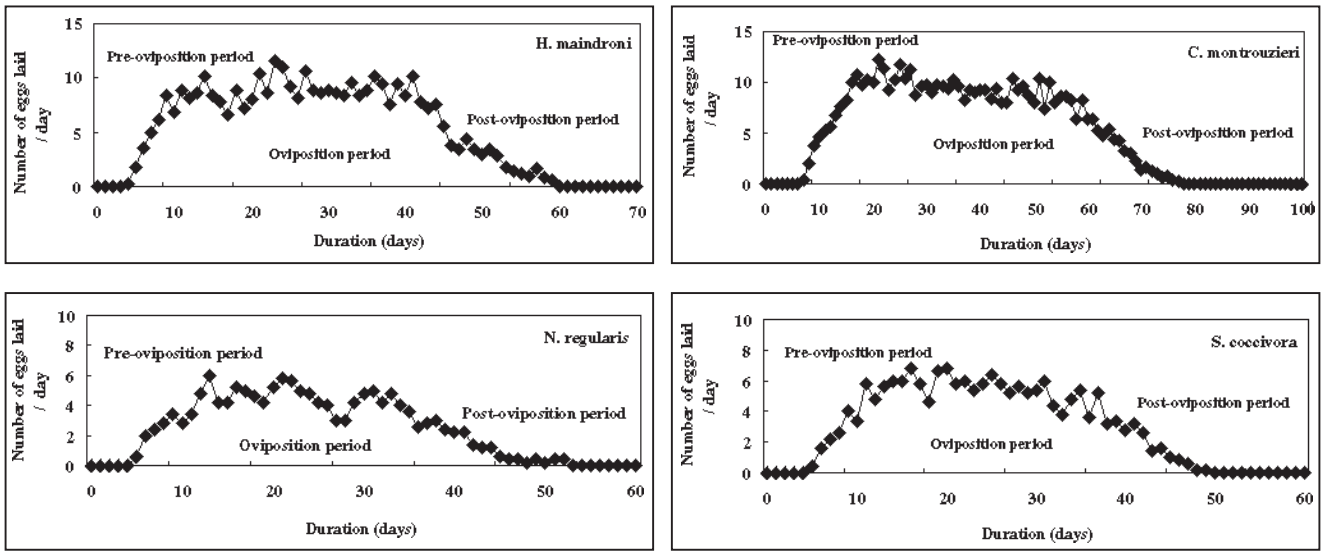

Fig. 1. Average daily oviposition of four coccinellids reared on *P. solenopsis*

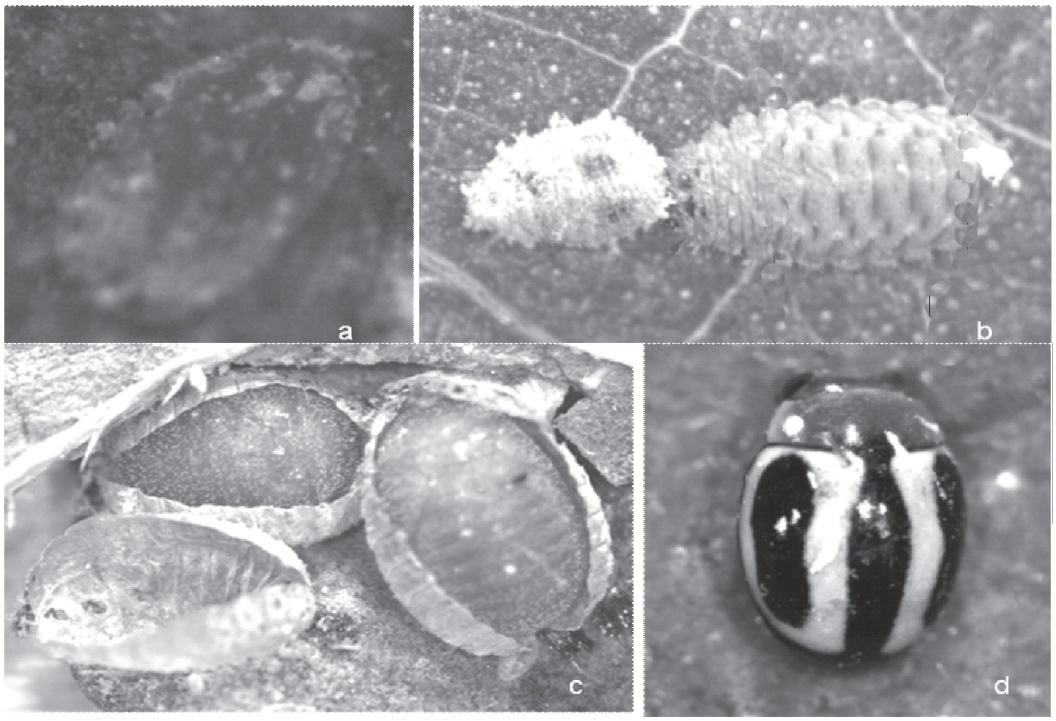

Plate 1. Stages of *H. maindroni*, a. Egg; b. Grub; c. Pupae; d. Adult

Table 3. Average daily oviposition and mean fecundity of coccinellid predators reared on *P. solenopsis*

Predator species	Oviposition (± SE) / day	Mean fecundity (± SE)
H. maindroni	7.6 ± 1.08[a]	370.20 ± .31[a]
C. montrouzieri	9.4 ± 0.93[a]	510.00 ± 9.73[b]
N. regularis	3.4 ± 0.51[b]	148.80 ± 3.85[c]
S. coccivora	4.4 ± 0.51[b]	183.80 ± 7.84[d]
CD (P ≤ 0.05%)	2.39	24.06

*Within columns, means followed by different letters indicate that the values are statistically significant (LSD, P ≤ 0.05%)

The eggs of *H. maindroni* were oval, elongate and transparent, measuring about 0.53 x 0.33 mm in size, covered with some host debris, laid singly in and around the mealybug colony (Plate 1a). Average incubation period was 4.9 ± 0.10 days after which the larva hatched out. The grub duration lasted for 15.30 days followed by a pupal period of 11.8 ± 0.37 days. The beetles started laying eggs after a preoviposition period of 5.40 ± 0.51 days and laid an average of 370.20 ± 9.31 eggs / female in 47.80 ± 2.42 days. Chatterjee (1954) reported *H. maindroni* as a potent natural enemy of *Phenacoccus insolitus* G. and *Aphis fabae* S. on brinjal from West Bengal, India. She *et al*. (1984) reported 5.1 days incubation period, 13.8 days larval period, 7.1 days pupal period and 6.3 days preoviposition period in *H. jucunda* (Mulsant) at 27°C. The generation cycle (egg to egg) was 32.8 days. The oviposition period was about 93 days during which the female laid an average of 456 eggs.

Cryptolaemus montrouzieri laid eggs in groups of 2-3 among the cottony ovisacs of the adult mealybugs. The eggs were oval, longer than broad and light yellowish to cream coloured (0.66 x 0.27 mm) (Plate 2a). Eggs hatched into larvae in about 5.5 ± 0.22 days. The four larval stages lasted for 14.8 days and the results are in agreement with Weeden *et al*. (2009), who reported 5.00 days incubation period and 12-17 days larval period in *C. montrouzieri* at 27.0°C. The preoviposition period in *C. montrouzieri* (6.8 ± 0.37 days) was supported by the findings of Persad and Khan (2002), who reported that in females of *C. montrouzieri* mating occurred after 4 days and egg laying started within 7 days of adult eclosion. The female laid on an average 510.00 ± 9.73 eggs in an average oviposition period of 62.20 ± 3.14 days. Weeden *et al*. (2009) reported that *C. montrouzieri* females laid a total of 400-500 eggs in their 50-day lifetime. Substantial work has been conducted on the biology of *C. montrouzieri* (Charansri and Nishida, 1975; Murthy, 1982; Babu and Azam, 1987).

The eggs laid by *N. regularis* (0.43 x 0.21mm size) were noticed in groups of three, characteristically stacked over the other around the mealybug colony (Plate 3a). The eggs hatched in about 4.7 ± 0.20 days and the grub duration lasted for 10.90 days. The beetles started

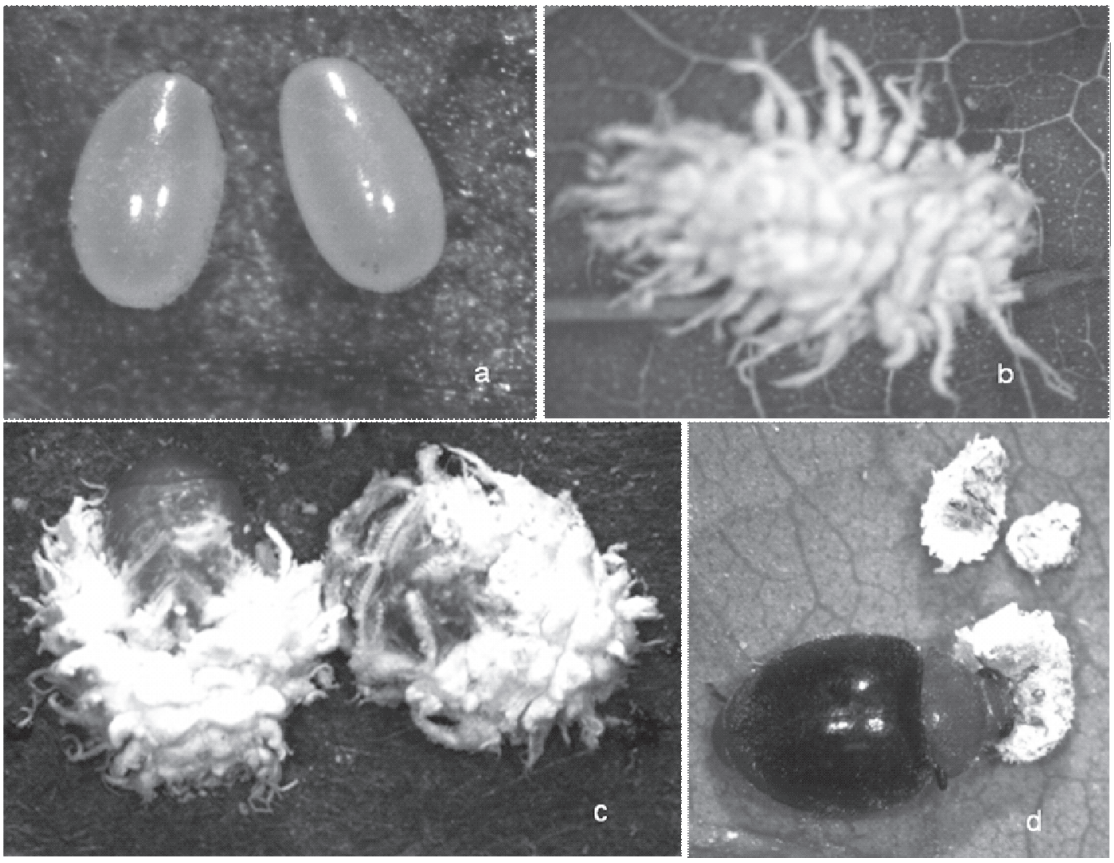

Plate 2. Stages of *C. montrouzieri.* a. Eggs; b. Grub; c. Pupae; d. Adult

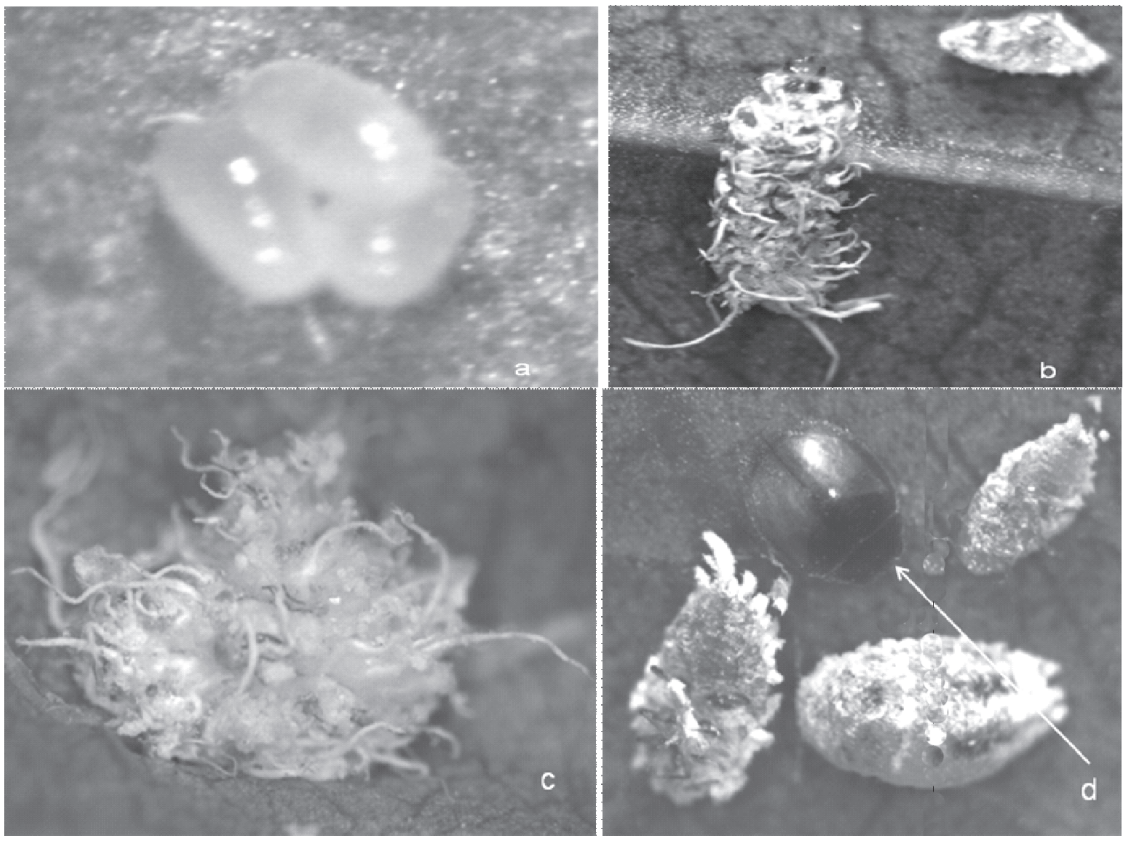

Plate 3. Stages of *N. regularis.* a. Eggs; b. Grub; c. Pupa; d. Adult

laying eggs after a preoviposition period of 4.40 ± 0.40 days. The egg laying was observed for 38.60 ± 2.54 days with a mean fecundity of 148.80 ± 3.85eggs / female. Canhilal *et al.* (2001) reported egg, grub and pupal periods of 4.4-6.1days, 10.3 days and 9 days, respectively, in *N. includens* Kirsch at 30°C. The development of *N. regularis* from egg to adult was completed in 25.4 ± 0.40 days, which is supported by the findings of Tranfaglia and Viggianni (1973) who reported that the development time from hatching to adult of *N. includens* was 25.9 days with a mean number of eggs laid 150.9 / female at 25-27°C.

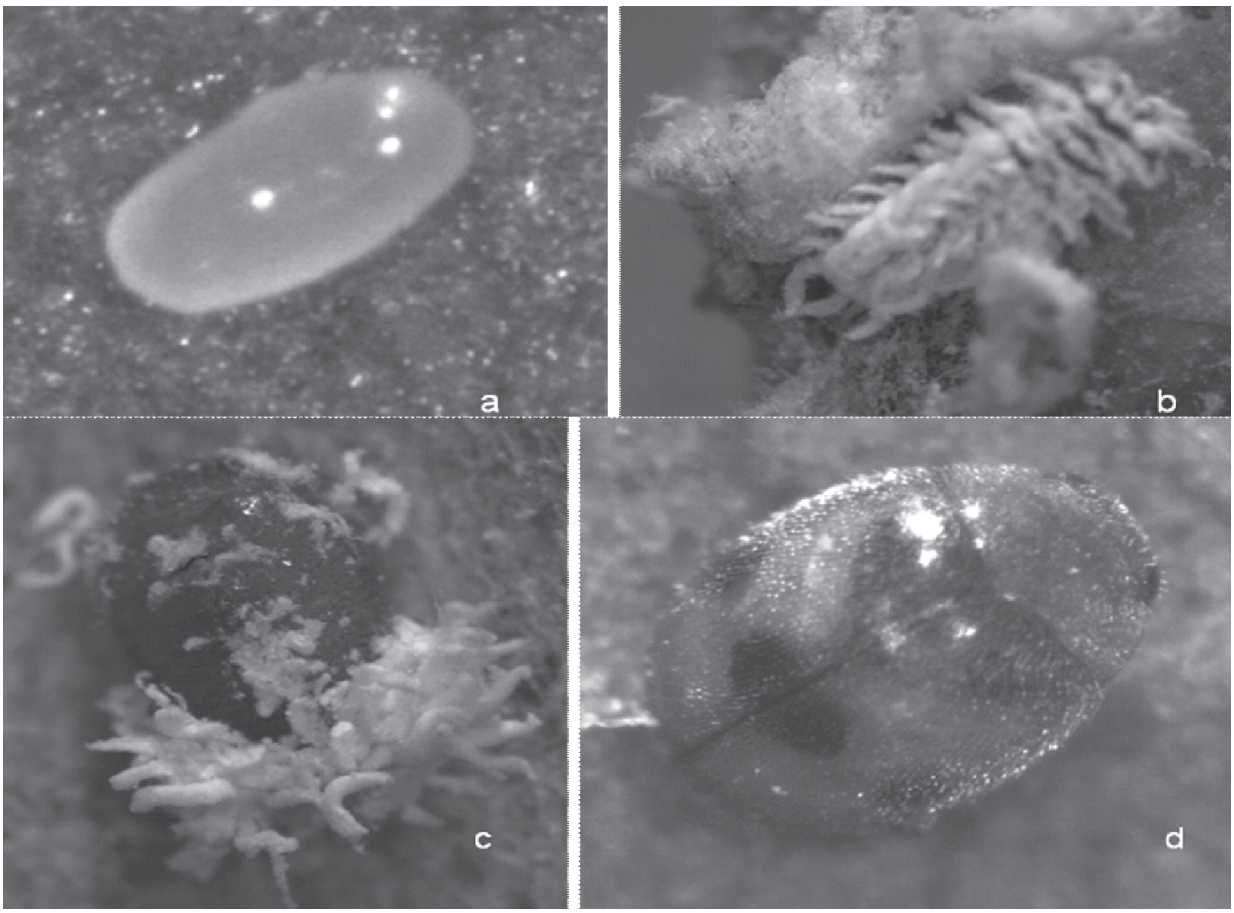

Plate 4. Stages of *S. coccivora.* a. Egg; b. Grub; c. Pupa; d. Adult

The eggs of *S. coccivora* (0.45 x 0.22mm) were laid singly among the mealybug colony (Plate 4a). Average incubation period was 4.5 ± 0.22 days. The larval duration was 8.7 days followed by 8.5 ± 0.22 days pupation. Egg laying started after 4.60 ± 0.24 days of preoviposition period and the beetles laid an average of 183.80 ± 7.84 eggs in 39.80±1.39 days. Several studies were carried out on the development and predatory potential of *Scymnus* sp. (Patro and Behera, 1992; Jayaraj and Gautam, 1993). Persad and Khan (2002) reported that in females of *S. coccivora*, mating occurred after 2 days of adult emergence. Atlihan and Chi (2008) reported that the total developmental time of *S. subvillosus* (Goeze) from egg hatch to adult eclosion ranged from 22.6 days at 20°C to 10.6 days at 35°C which was closer to the present finding where the development period was 21.7 ± 0.20 days.

In the present study, all the four species of coccinellids were reared on the same prey under similar conditions and hence, the differences in their life cycle durations can only be attributed to their inherent ability to utilize the prey effectively and complete various life processes. The results give an important implication for developing laboratory mass production techniques, a prerequisite for successful biological control. Besides classical biological control approach, the role of indigenous natural enemies in pest control is attracting attention because of their adaptability to diverse crop habitats and amenability to mass production. Further, studies are needed to exploit the predatory potential of indigenous coccinellids successfully in IPM programme.

ACKNOWLEDGEMENTS

The authors express sincere gratitude to Dr. H. S. Gaur, Dean, Post Graduate School, Indian Agricultural Research Institute, New Delhi for providing financial assistance in the form of Ph.D. Fellowship to carry out the present investigations. Sincere thanks go to Dr. G. T. Gujar, Head, Division of Entomology, IARI, New Delhi, for providing the necessary facilities during the course of research work. The authors would like to acknowledge an anonymous reviewer for determining the identity of *Hyperaspis maindroni*.

REFERENCES

Atlihan, R. and Chi, H. 2008. Temperature dependent development and demography of *Scymnus subvillosus* (Coleoptera: Coccinellidae) reared on *Hyalopterus pruni* (Homoptera: Aphididae). *Journal of Economic Entomology*, **101**: 325-333.

Babu, R. and Azam, K. M. 1987. Biology of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera) in relation with temperature. *BioControl,* **32**: 381-386.

Canhilal, R., Uygun, N. and Carner, G. R. 2001. Effects of temperature on development and reproduction of a predatory beetle, *Nephus includens* Kirsch (Coleoptera: Coccinellidae). *Journal of Agriculture and Urban Entomology,* **18**: 117-125.

Chandrababu, A., Gautam, R. D. and Garg, A. K. 1999. Biology of ladybird beetle, *Brumoides suturalis* (Fabricius) on aphid and mealybugs. *Annals of Plant Protection Sciences,* **7**: 13-18.

Charansri, V. and Nishida, T. 1975. Relative abundance of three coccinellid predators of the green scale (*Coccus viridis* Green) on Plumeria trees. *Proceedings of the Hawaiian Entomological Society,* **22**: 22-23.

Chatterjee, N. C. 1954. Biological control of the brinjal mealybug and aphids by *Hyperaspis maindroni* Sicard. *Current Science*, **23**: 133.

Dhawan, A. K., Singh, K., Saini, S., Mohindru, B., Kaur, A., Singh, G. and Singh, S. 2007. Incidence and damage potential of mealybug, *Phenacoccus solenopsis* Tinsley on cotton in Punjab. *Indian Journal of Ecology*, **34**: 110-116.

Gautam, R. D. 2008. *Biological pest suppression*. Westville Publishing House, New Delhi. 221pp.

Gautam, R. D., Usha Saxena, Sudhida Gautam, Khan, M. A. and Gautam, C. P. N. 2007. Studies on solanum mealybug, *Phenacoccus solani* Ferris (Hemiptera: Pseudococcidae), its parasitoid and predator complex, reproductive potential and utilization as laboratory prey for rearing the ladybird and green lacewing predators. *Journal of Entomological Research,* **31**: 1-6.

Jayaraj, J. and Gautam, R. D. 1993. Feeding potential and field utilization of *Scymnus brunnescens* Motsch. (Coccinellidae: Coleoptera) as biocontrol agent against pseudococcids. In: *5th National Symposium on Advances in Biological Control of Insect Pests.* October, 2-3, 1991.

Jhala, R. C., Bharpoda, T. M. and Patel, M. G. 2008. *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae), the mealybug species recorded first time on cotton and its alternate host plants in Gujarat, India. *Uttar Pradesh Journal of Zoology,* **28**: 403-406.

Murthy, M. S. 1982. Studies on the biology and habits of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera). M.Sc. (Agriculture) Thesis, Andhra Pradesh Agricultural University, Hyderabad, India.

Patro, B. and Behera, M. K. 1992. Development and feeding potential of *Scymnus* sp. on the bean aphid, *Aphis craccivora. Journal of Biological Control*, **6**: 64-66.

Persad, A. and Khan, A. 2002. Comparison of life table parameters for *Maconellicoccus hirsutus, Anagyrus kamali, Cryptolaemus montrouzieri* and *Scymnus coccivora*. *BioControl,* **47**: 137-149.

Poorani, J. 2004. An annotated checklist of the Coccinellidae (Coleoptera) of the Indian Subregion. http://www.angelfire.com/bug2/j_poorani/, accessed on: 25/01/2010.

She, H. D. N., Odebiyi, J. A. and Herren, H. R. 1984. The biology of *Hyperaspis jucunda* (Col.: Coccinellidae), an exotic predator of the Cassava mealybug *Phenacoccus manihoti* (Hom.: Pseudococcidae) in Southern Nigeria. *BioControl,* **29**: 87-93.

Tanwar, R. K., Jeyakumar, P. and Monga, D. 2007. *Mealybugs and their management.* Technical Bulletin **19,** September, 2007. National Centre for Integrated Pest Management, LBS Building, Pusa Campus, New Delhi 110 012.

Tranfaglia, A. and Viggianni, G. 1973. Biological data on *Scymnus includens* (Col., Coccinellidae). *Bolletino del Laboratoria di Entomologia Agraria Flippo Silvestri Portici* (RAE (A) 1975, 63 Abstr. 1267).

Weeden, C. R., Shelton, A. M. and Hoffman, M. P. 2009. Biological Control: A Guide to Natural Enemies in North America. Cornell University, USA. http://www.nysaes.cornell.edu/ent/biocontrol/, accessed on: 13/03/2009.