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Research Article

Effect of developmental stage and density of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on the predatory performance of four coccinellid predators

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ABSTRACT: The predatory performance of four coccinellid predators, *viz*., *Hyperaspis maindroni*, *Cryptolaemus montrouzieri*, *Nephus regularis* and *Scymnus coccivora*, was studied on *Phenacoccus solenopsis* under laboratory conditions at 27 ± 2°C and 65 ± 5% RH. The grubs of all the four predators preferred to prey upon second instar mealybugs followed by third instars and adults when given the choice and fourth instar grubs were the most voracious. The overall predation by the grubs of *C. montrouzieri* (170.40 mealybugs) was significantly higher than that of the rest of the species. The rate of predation was dependent on developmental period and per day consumption of grubs of all the stages decreased with increase in size of the mealybug. Mean number of *P. solenopsis* individuals consumed and number of eggs laid per day by the females of all the predators increased gradually with prey density from lower to higher densities, but at a decreased rate.

KEY WORDS: *Phenacoccus solenopsis*, *Hyperaspis maindroni, Cryptolaemus montrouzieri,* feeding potential, *Nephus regularis, Scymnus coccivora,* starvation potential

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INTRODUCTION

More than 100 species of mealybugs are known to attack a variety of plant species in India (Varshney, 1985). In the current decade, increased build up of various mealybug species in crop plants and in the wild has been observed mainly due to globalization and liberalization of agricultural trade as well as certain abiotic changes in climate and environment (Tanwar *et al.,* 2007; Gautam *et al.,* 2009). The solenopsis mealybug, *Phenacoccus solenopsis* Tinsley, has recently emerged as a serious insect pest in India, attacking important field crops such as cotton, okra, tomato, brinjal, chilli and ornamental plants such as hibiscus, particularly in the cotton growing belts of Punjab, Haryana, Gujarat, Maharashtra and Andhra Pradesh (Dhawan *et al.,* 2007; Tanwar *et al.,* 2007; Jhala *et al.,* 2008). The mealybug has spread throughout the country (Tanwar *et al.,* 2007; Jhala *et al.,* 2008) causing devastation.

Coccinellids are the most widespread and abundant predators in many agricultural ecosystems. They are known to have strong impact on populations of sucking pests, especially aphids (Osawa, 2000), coccids and mealybugs (Hodek, 1973) based on which they are categorized broadly as aphidophagous and coccidophagous ladybirds, respectively. A large number of ladybird beetles, *viz., Hyperaspis maindroni* Sicard [earlier reported as *Brumoides lineatus* (Weise), Gautam *et al.,* 2007], *Brumoides suturalis* (Fabricius), *Cheilomenes sexmaculata* (Fabricius), *Nephus regularis* Sicard and *Scymnus coccivora* Ayyar have been recorded on *P. solenopsis* in India (Tanwar *et al.,* 2007).

The present investigation was carried out on the predatory potential of *H. maindroni, Cryptolaemus montrouzieri* Mulsant*, N. regularis* and *S. coccivora* to compare the feeding capacity as affected by the developmental stage and density of *P. solenopsis* and to find out the most potent predator to be recommended for effective and holistic mealybug management.

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 by following Gautam (2008).

Rearing of host insect, P. solenopsis

The mealybug culture was maintained in the laboratory on sprouted potato tubers (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 hair brush. 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 developed fully after 10-12 days, which was used for further studies.

Rearing of coccinellid predators

The nucleus cultures of *H. maindroni, C. montrouzieri, S. coccivora* and *N. regularis* were maintained on the mealybug infested sprouted potato tubers in the laboratory. Five pairs of the predators were 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 maintained at 27 ± 2°C and 65 ± 5% RH.

Feeding preference of coccinellid grubs as affected by prey stage

Individuals of *P. solenopsis,* approximately of the same size for each instar, were selected for the experiment. Second and third instar nymphs and adult females were used. Using a camel hair brush, 50 mealybugs of the same instar were transferred into a glass vial in which the newly hatched grub was released individually. The food was changed daily and the numbers eaten were counted for each instar of the mealybug. The experiment was continued throughout the larval period of the predators and instarwise feeding potential was calculated. Five replicates were kept for each stage of the mealybug and predators.

Prey consumption and fecundity of coccinellids in relation to prey density

Newly emerged adults were fed with honey (20%), paired randomly and kept in small glass vials with sufficient prey till mating. Ten-day-old females of each species of coccinellid were starved for 24 hours before use in the experiment. The females were kept individually in 10 x 2.5 cm glass vials and held at 27 ± 2°C and 65 ± 5% RH. They were provided with 10, 20, 30 and 40 mealybugs (mixed population of second and third instars) separately. Number of mealybugs eaten and eggs produced per day by each female were recorded daily for a week. To maintain the reproductive vigour of the beetles, after three days of the experiment, males were released in each vial and allowed to mate for about 2 h. The experiment was replicated for five times at each prey density (Agarwala and Bardhanroy, 1999; Agarwala *et al.,* 2001).

Starvation potential

In order to determine the ability of the predators to sustain the periods of food scarcity, the different developmental stages of the coccinellids were caged individually in small glass vials with no food. They were observed till death and the durations of survival were recorded for different stages of each species.

Statistical analysis

The data obtained from replicated trials on the parameters under consideration were subjected to one-way analysis of variance (arcsine transformation was applied wherever necessary) in SPSS statistical programme (version 13.0) for the interpretation of results. 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 $P < 0.05\%$. For functional and numerical responses, the regression line was fitted to the data using Microsoft Office Excel-2007 programme.

RESULTS AND DISCUSSION

The grubs of all the four predators preferred second instar mealybugs to the others (Table 1) and fed by puncturing the mealybug body from postero-ventral side and left only a small portion of the cadaver after feeding. The adults when fully fed, start scraping the mealy / waxy coating on the mealybug body thereby making them more vulnerable to body moisture loss and / or attack by the natural enemies. A typical behaviour found only in the adults of *C. montrouzieri* is the scooping of the dorsal side of the abdomen of adult mealybugs with its mandibles, thereby exposing the eggs inside which shrivel and do not hatch. The injured mealybugs stop / reduce feeding, become immobile and die within 1-2 days following the injury. Thus, indirectly it adds to the control potential of *C. montrouzieri*.

The predatory response of different developmental stages of the four coccinellids exhibited significant differences with respect to the developmental stages of *P. solenopsis*. The grub stages preferred the second

instars followed by third instar and adult mealybugs. Irrespective of the species, the fourth instar was the most voracious. Overall feeding potential of *C. montrouzieri* was considerably higher than that of the other species. It was also observed that per day consumption of grubs of all the stages decreased with increase in the size of the mealybug (Table 1). Increase in feeding potential with age of the grubs is in line with the findings of Elliot *et al.* (1994), Babu (1999) and Ali and Rizvi (2007).

The mean number of *P. solenopsis* eaten per day by the females of the four coccinellid predators increased gradually from low to higher densities. However, the proportion of mealybugs eaten per day decreased at higher densities of prey. In general, there was an increase in the number of prey consumed, but at a decreasing rate with increase in the density of prey offered (Table 2). Regression analysis showed that a curvilinear (polynomial) response is a better statistical fit to the data (Fig. 1; *H. maindroni*, $y = 0.364x + 4.2$, $R^2 = 0.962$; *C. montrouzieri*, $y = 0.001x^2 + 0.314x + 5.4$, $R^2 = 0.962$; *N. regularis*, $y = 0.001x^2 + 0.102x + 3.6$, $R^2 = 0.989$; *S. coccivora*, $y = 0.001x^2 + 0.099x + 3.25$, $R^2 = 0.999$). The decreasing efficiency of prey consumption at higher densities of *P. solenopsis* exhibited by adult beetles in the present study is supported by the findings of Hodek (1973) who reported that hungry coccinellids completely devour the first few prey they attack, but exploit subsequent prey with a gradually decreasing efficiency. Jalali and Singh (1993) also reported that when larvae of *C. sexmaculata* were given 25 *Aphis gossypii* Glover nymphs per day, they consumed 79.20%, but the percentage decreased to 70.30% when prey density increased to 50 nymphs per day.

In our study, partial consumption of the prey was observed at higher prey densities of 30 and 40 nymphs per day. This indicates that the maximum possible intake by predacious beetles is in the range of 20-30 nymphs per day, above which their prey utilization efficiency decreases. This is in conformity with Uygun and Atlihan (2000) who reported that the consumption rate of larvae and adults of *Scymnus levaillanti* (Mulsant) increased with increasing prey densities up to 32 *A. gossypii*/day and then leveled off.

The mean number of eggs laid per day by the females of all the coccinellid predators increased gradually with prey density, but at a decreasing rate (Table 2) and it reached its upper asymptote at a prey density of 40 mealybugs per female as the number of eggs laid were not significantly different from that at a prey density of 30 mealybugs per female. By regression analysis it was found that a curvilinear (polynomial) response provided a better statistical fit to the data (Fig. 2; *H. maindroni,* $y = -0.007x^2 + 0.586x + 0.6$, $R^2 = 0.962$; *C. montrouzieri*, $y = -0.005x^2 + 0.578x + 1.7$, $R^2 = 0.877$; *N. regularis,* $y = -0.004x^2 + 0.272x$, $R^2 = 0.961$; *S. coccivora,* $y = 0.003x^2 + 0.261x + 0.45$, $R^2 = 0.962$).

The starvation potential of the grubs increased with their age. In general, females survived longer than males in the absence of food in all the four species. Overall, *C. montrouzieri* sustained starvation longer than the other three species (Table 3).

Consumption rates obtained in this study may be higher than that in nature because the searching time for the predators might have decreased significantly since they were confined to small vials along with the prey.

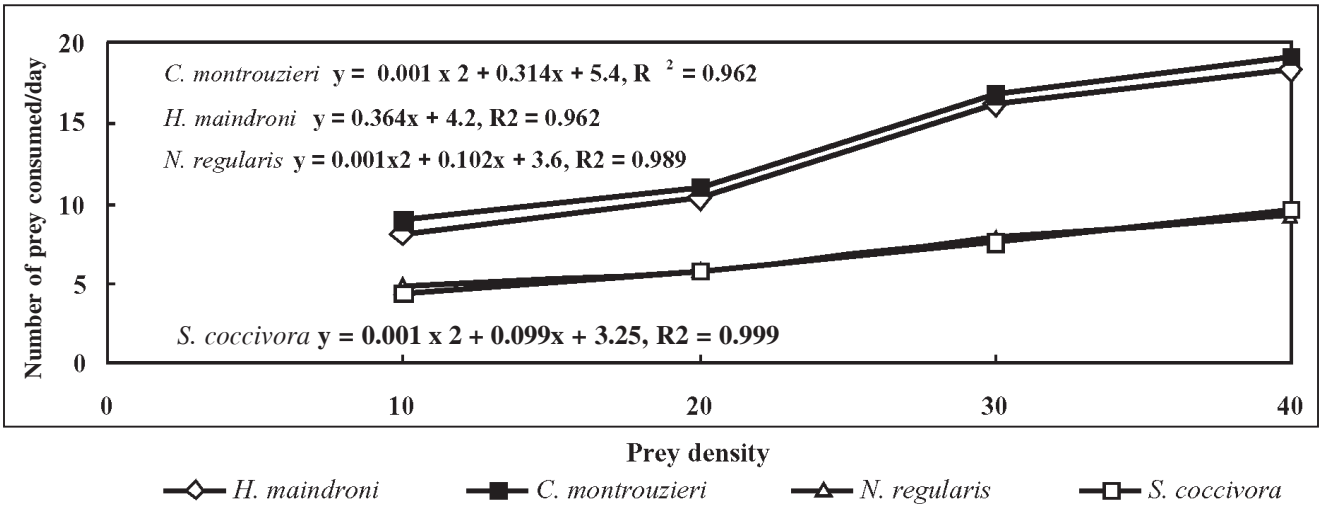

Fig. 1. Mean number of prey consumed per day by female coccinellids at increasing density of *P. solenopsis*

Table 1. Consumption of *P. solenopsis* by different instars of coccinellid predators in relation to prey stage

Predator stage	Mean number of prey consumed (± SE) / day											
	Stage of the mealybug											
	II instar				III instar				Adult			
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4
I instar	5.00±0.45[a]	7.00±0.32[a]	4.60±0.24[a]	4.40±0.24[a]	4.00±0.32[a]	5.40±0.24[a]	4.00±0.32[a]	3.00±0.32[a]	3.00±0.32[a]	4.20±0.37[a]	2.80±0.37[a]	2.60±0.24[a]
II instar	8.00±0.32[b]	10.80±0.37[b]	7.00±0.45[b]	7.00±0.32[b]	6.20±0.73[b]	8.20±0.37[b]	6.00±0.45[b]	4.40±0.24[b]	4.80±0.37[b]	6.60±0.40[b]	3.40±0.24[a]	3.20±0.20[b]
III instar	20.40±0.51[c]	27.80±0.58[c]	14.00±0.55[c]	14.60±0.51[c]	15.40±0.51[c]	19.40±0.51[c]	9.80±0.37[c]	10.20±0.37[c]	9.40±0.51[c]	13.20±0.37[c]	6.00±0.32[b]	5.40±0.24[c]
IV instar	39.00±0.71[d]	42.80 ± 1.02[d]	20.40±0.75[d]	19.20±0.58[d]	29.20±0.58[d]	32.60±0.51[d]	14.20±0.37[d]	14.60±0.51[d]	13.60±0.60[d]	18.00±0.45[d]	9.20±0.37[c]	9.60±0.24[d]
CD (P<0.05%)	1.54	1.91	1.58	1.30	1.67	1.27	1.14	1.12	1.39	1.20	0.99	0.70

* Within columns, means followed by different letters are statistically significant (LSD, $P < 0.05\%$); P_1 = *H. maindroni,* P_2 = *C. montrouzieri,* P_3 = *N. regularis* and P_4 = *S. coccivora*

Table 2. Mean proportion (arcsine transformed) of prey consumed and fecundity per day by females of coccinellid predators at various prey densities

Predator species	Mean proportions (± SE) of prey consumed per density offered				Mean proportions (± SE) of eggs produced per density offered			
	Prey density offered						Prey density offered	
	10	20	30	40	10	20	30	40
H. maindroni	0.6536±0.02810[a]	0.4615±0.01468[a]	0.4730±0.01273[a]	0.4270±0.0098[a]	0.5087±0.02636[a]	0.4153±0.01922	0.4038±0.01805	0.3410±0.0117[a]
C. montrouzieri	0.7598±0.06326[a]	0.4789±0.01594[a]	0.4845±0.0072[a]	0.4385±0.0084[a]	0.6398±0.07534[b]	0.4325±0.02683	0.4771±0.0199	0.3947±0.0184[b]
N. regularis	0.4385±0.02158[b]	0.3254±0.01177 [b]	0.3059±0.0129[b]	0.2860±0.0115[b]	0.2922±0.01628[c]	0.2498 0.01452	0.2352±0.0097	0.1929±0.0096[c]
S. coccovora	0.4500±0.0000[b]	0.3246±0.01876[b]	0.3015±0.0132[b]	0.2925±0.0138[b]	0.3176±0.02388[c]	0.2650±0.01141	0.2501±0.0165	0.2102±0.0123[c]
CD (P < 0.05%)	0.1087	0.0464	0.0353	0.0331	0.1272	0.0567	0.0469	0.0401

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

Table 3. Starvation potential (± SE) of different developmental stages of coccinellid predators

Developmental stage		Starvation potential (days) ± SE				CD (P < 0.05%)
		H. maindroni	*C. montrouzieri*	*N. regularis*	*S. coccivora*	
Grub	I instar	1.80 ± 0.57[a]	2.00 ± 0.35[a]	1.50 ± 0.35[a]	1.70 ± 0.27[a]	0.54
	II instar	2.40 ± 0.19[ab]	2.60 ± 0.19[b]	2.00 ± 0.16[a]	2.20 ± 0.20[ab]	0.55
	III instar	3.30 ± 0.25[a]	4.00 ± 0.16[b]	3.10 ± 0.19[a]	2.70 ± 0.20[a]	0.61
	IV instar	4.60 ± 0.29[a]	5.30 ± 0.25[a]	3.90 ± 0.19[ab]	3.10 ± 0.19[c]	0.70
Adult	Male	9.10 ± 0.40[a]	13.40 ± 0.51 [b]	7.70 ± 0.37[c]	7.62 ± 0.24[c]	1.19
	Female	11.20 ± 0.58[a]	16.10± 0.40[b]	8.50 ± 0.45[c]	8.10 ± 0.19[c]	1.28

* Within rows means followed by different letters are statistically significant (LSD, $P < 0.05\%$)

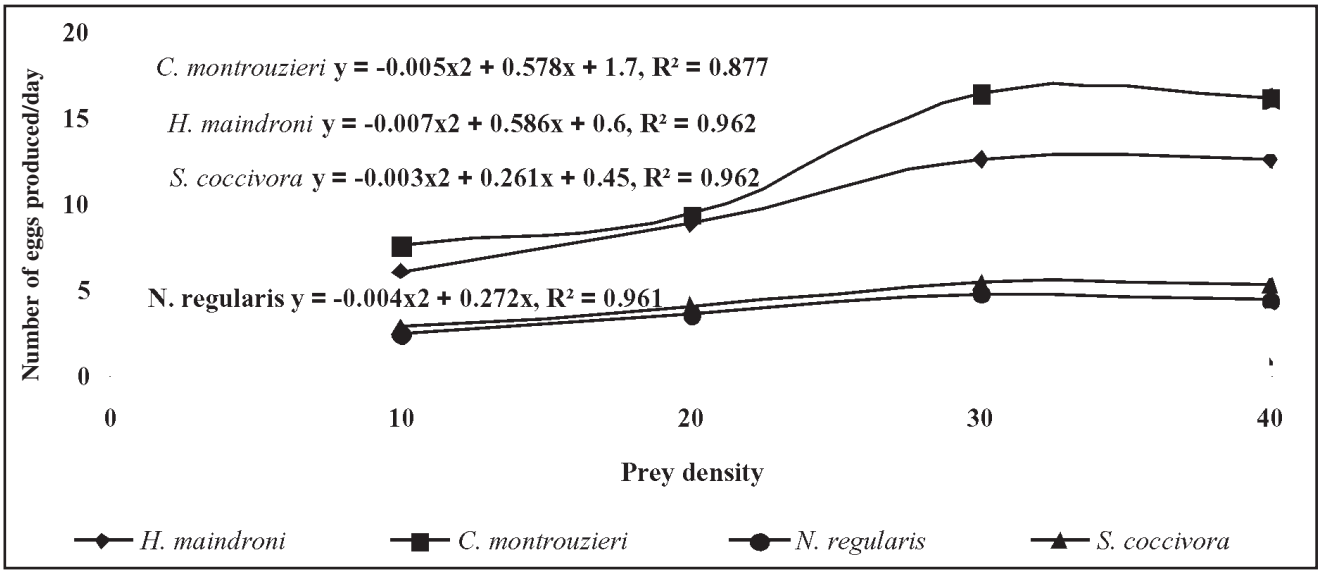

Fig. 2. Mean number of eggs produced per day by female coccinellids at increasing density of *P. solenopsis*

It may again increase the activity of the predators under laboratory conditions, especially at higher prey densities.

The present study revealed *C. montrouzieri* and *H. maindroni* as more efficient predators than *S. coccivora* and *N. regularis* for *P. solenopsis*. 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 under field conditions.

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REFERENCES

Agarwala, B. K. and Bardhanroy, P. 1999. Numerical response of ladybird beetles (Coleoptera: Coccinellidae) to aphid prey (Homoptera: Aphididae) in field bean in north-east India. *Journal of Applied Entomology*, **123**: 401–405.

Agarwala, B. K., Bardhanroy, P., Yasuda, H. and Takizawa, T. 2001. Prey consumption and oviposition of the aphidophagous predator *Menochilus sexmaculatus* (Coleoptera: Coccinellidae) in relation to prey density and adult size. *Environmental Entomology*, **30**: 1182–1187.

Ali, A. and Rizvi, P. Q. 2007. Development and predatory performance of *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) on different aphid species. *Journal of Biological Sciences*, **7**: 1478–1483.

Babu, A. 1999. Influence of prey species on feeding preference, post-embryonic development and reproduction of *Coccinella transversalis* F. (Coleoptera: Coccinellidae). *Entomon*, **24**: 221–228.

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.

Elliot, N. C., French, B. W., Michels, J. G. J. and Reed, D. K. 1994. Influence of four aphid prey species on development, survival and adult size of *Cycloneda ancoralis* (Germar) (Coleoptera: Coccinellidae). *Southwest Entomology*, **19**: 57–61.

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

Gautam, R. D., Suroshe, S. S., Gautam, S., Saxena, U., Fand, B. B. and Gupta, T. 2009. Fortuitous biological control of exotic mealybug, *Phenacoccus solenopsis* - a boon for Indian growers. *Annals of Plant Protection Sciences,* **17**: 38–39.

Gautam, R. D., Saxena, U., Gautam, S., 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.

Hodek, I. 1973. *Biology of Coccinellidae*. W. Junk, The Hague.

Jalali, S. K. and Singh, S. P. 1993, Effect of *Aphis gossypii* Glover number on *Mallada astur* (Banks) and *Cheilomenes sexmaculata* (Fabricius). *Biological Control*, **4**: 45–47.

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.

Osawa, N. 2000. Population field studies on the aphidophagous ladybird beetle *Harmonia axyridis* (Coleoptera: Coccinellidae): resource tracking and population characteristics. *Population Ecology*, **42**: 115–127.

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

Uygun, N. and Atlihan, R. 2000. The effect of temperature on development and fecundity of *Scymnus levaillanti*. *BioControl*, **45**: 453–462.

Varshney, R. K. 1985. A review of Indian coccids (Homoptera: Coccoidea). *Oriental Insects*, **19**: 1–101.