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Biology and feeding potential of *Geocoris superbus* Montandon (Heteroptera: Geocoridae), a predator of mealybug

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Abstract
The present research was undertaken to study the biology and feeding potential of *Geocoris superbus* Montandon (Heteroptera: Geocoridae), a predator of mealybug, collected from Jamun and Indian Banyan tree (*Ficus benghalensis)* at National Bureau of Agricultural Insect Resources, Bangalore during the year 2015-16. It inhabits the leaf-margins of roll galls produced by *Trioza* sp. (Hemiptera: Sternorrhyncha: Triozidae) on the leaves of *Ficus benghalensis*. Inside these rolled leaves the geocorid was associated with aphids, thrips and mealybug, *Phenacoccus sp.* This niche was shared with predatory mirid, *Chimairacoris lakshimiae* Yasunaga, Schuh, and Cassis (Miridae) and an undescribed species of the genus *Anthocoris* Fallén (Anthocoridae). In jamun also it was found inside the leaf roll and associated with mealybugs and aphids. The morphometry and biology of this predator were studied. *G. superbus* nymphs and adults could be reared on UV irradiated eggs of the angoumois moth *Sitotroga cerealella.* The adults of *G. superbus* were provided with *Helicoverpa armigera* eggs or *Phenacoccus solenopsis* nymphs in addition to *Sitotroga cerealella* eggs, for better survival. A total of five nymphal instars were recorded and the total developmental period was 41.2 days with a nymphal period of 31.2 days. Preoviposition period of 9 days and percent hatching of 83% were recorded. Longevity of adult male and female was 24.8 and 30 days, respectively. Mean fecundity per female was 29.4 eggs.

Keywords: Anthocoridae, biology, *Geocoris superbus*, *Ficus benghalensis*, Mirid

1. Introduction
Most of the Lygaeidae are phytophagous insects. Sweet described seed feeding as the generalized and characteristic feeding habit of the Lygaeids [1]. He also observed that Geocorinae was the only subfamily within this group known to be predaceous. Big eyed bugs or *Geocoris* spp. Fallen (Hemiptera: Lygaeidae) are generalist insect omnivores which occur worldwide [2]. Polyphagous predators may be effective bioagents as they do not rely totally on a target pest; their dynamics can be positively enhanced by alternate prey [3].
From India, so far 10 species of *Geocoris* Fallen have been reported from West Bengal and 23 species from rest of India [4]. They are prevalent in different crop ecosystems and shared the niche with many other predators [5-8]. These predators include anthocorids and coccinellids. Geocorids are general predators. They feed on eggs, neonates, nypmphs, aphids, thrips, and mites [2, 9-14]. Life history traits of various *Geocoris* spp have been studied viz. *G. atricolor* Montandon, *G. pallens* Stäl [15], *G. lubra* Kirkaldy [16] and *G. punctipes* (Say) [9, 17]. In India, few studies have been conducted on Geocorids and it is limited to commonly found species, *Geocoris ochropterus* Fieber. This species is prevalent in sunflower, cotton, lucerne, maize and tea ecosystems feeding on several insect pests. However, current study is focused on another geocorid, i.e. *Geocoris superbus* Montandon. *Geocoris superbus* which is also a very good predator of soft bodied insects and found feeding on mealybugs (personal observation). *Geocoris superbus* inhabits the leaf-margin roll galls produced by psyllid, *Trioza sp*. (Hemiptera: Sternorrhyncha: Triozidae) on the leaves of Indian banyan tree (*Ficus benghalensis*). This psyllid folds and tightly rolls one or both margins of the *Ficus* leaves, and *G. superbus* nymphs remain sheltered inside these roll galls, along with mealybug, *Phenacoccus parvus* Morrison (Sternorrhyncha: Pseudococcidae), Thrips, aphids, predatory mirid *Chimairacoris lakshimiae* Yasunaga, Schuh, and Cassis (Miridae) and an undescribed species of the genus *Anthocoris* Fallén (Anthocoridae) [18]. In Jamun also it is found inside the leaf roll and associated with mealybugs and aphids. Through the current study attempts were made to rear this predator in the laboratory and to study its morphometry and biology.

The objective of this work was to study its biology and to develop rearing protocol to meet the predator requirement for large-scale releases. Thus, this paper details a method of *Geocoris superbus* rearing on eggs of alternate laboratory host, *S. cerealella* eggs and mealybug.

2. Material and Methods

Laboratory studies were conducted at 26±2 ^{O}C and 65±2% relative humidity in mass production laboratory of National Bureau of Agricultural Insect Resources (NBAIR), Bangalore during 2015-16. UV-irradiated *S. cerealella* eggs were obtained from Dr. Sunil Joshi, NBAIR, Bangalore and utilized as laboratory host. Besides that *Phenacoccus solenopsis* was also used for feeding. Mealybug was collected from *Hibiscus* plant. Predators were initially collected from banyan tree, jamun and mango orchard and acclimatized under laboratory conditions by rearing for three generations on *S. cerealella* eggs and mealybug before initiating the experiments.

2.1 Biology

The adult geocorids lays eggs singly on cotton or cloth. From the lab reared *G. superbus* culture, one pair of adult was released into each pearl pet plastic container (200 ml) covered with black cloth. Ten such sets were maintained. Each container was provided with UV-irradiated *S. cerealella* eggs and *Phenacoccus solenopsis* as feeding, cotton wick for egg laying and bean pieces (2-3) for maintaining moisture. After every 24 h, cotton wicks were collected and observed under microscope to record number of eggs laid. Eggs were laid on cloth surface too. These were collected, counted and placed in small, round, ventilated jewel boxes for hatching separately.

The number of nymphs, which hatched from total eggs collected from each container, was counted for calculating per cent hatching. Ten freshly hatched nymphs per set were kept individually in jewel boxes provided with UV-irradiated *S. cerealella* eggs. Observations were recorded on total number of instars, duration of each instar and total nymphal period. The remaining nymphs from each set were reared in plastic container (200 ml) upto second instar. Cotton lint was provided in the containers to avoid cannibalism. From the 3rd instar stage, they were shifted to a fresh plastic container (500 ml). When adults were formed, they were collected and observed under microscope to differentiate the sex. Per cent adults formed was calculated based on the number of healthy adults developed from the total number of nymphs which hatched in each set. *Phenacoccus solenopsis* (mealybug) was provided for adult as feed. Longevity of adult *G. superbus* male and female was recorded. Morphometrics of egg, nymphal and adult stages were measured by using ocular and stage micrometers.

2.2 Feeding potential

To study the feeding potential in the laboratory, nymphs and adults of the second generation were used. Freshly hatched nymphs were kept individually in jewel boxes. Twenty UV-irradiated *S. cerealella* eggs were pasted on bean pod for 1st and 2nd instar grub, for 3rd instar grub 30 eggs and for 4th and 5th instar grubs, 50 UV-irradiated *S. cerealella* eggs were pasted on bean pod and placed inside each box. For adults 60 UV-irradiated *S. cerealella* eggs were pasted on bean pod. After every 24 h, the eggs were examined under microscope for feeding damage and the number of eggs fed was recorded. When adults were formed, the same procedure was followed to check their feeding potential.

2.3 Statistical analysis

Each experiment was replicated five times and the arithmetic mean and standard error of mean were estimated for all the parameters/observations. Range values were also estimated by pooling up the replication data for each parameter.

3. Results

Freshly laid eggs were ovoid and transparent with notches at the blunt end. On maturity eggs turn yellow and develop red eye spot on blunt end. Red zig zag structure was visible which start from lower end and occupy the middle area. The mean length and breadth of *G. superbus* egg were 0.42 and 0.98 mm, respectively (Table 1).

Table 1: Morphometry of *Geocoris superbus*

Developmental stage		Width (mm)	Length (mm)
		Mean±SEM	**Mean±SEM**
Egg		0.42±.003	0.98±.008
Nymph	1st instar	0.56±.004	1.05±.004
	2nd instar	1.08±.009	1.65±.008
	3rd instar	1.53±.012	2.15±.003
	4th instar	1.77±.032	2.71±.008
	5th instar	1.84±.020	3.31±00.350
Adult	Male	1.92±.020	4.13±.100
	Female	2.38±.005	4.75±.020

The newly hatched nymph of *Geocoris superbus* had a yellow head; thorax was yellow with slight black. It was having castaneous eyes and rest of the body was yellowish red in colour. Legs and anteneae were light yellow in colour except tibia which was deep brown. Rostrum was light yellow with 4 segments. A total of five instars were observed. The first, second, third, fourth and fifth instars measured 0.56, 1.08, 1.53, 1.77 and 1.84 mm, respectively, in breadth and 1.05, 1.65, 2.15, 2.71 and 3.31 mm, respectively in length (Table-1). The fifth instar molted to become an adult which was orange in colour with fully developed wings. After one day, the adults turn black in colour with brilliant ochraceous yellow head and pronotum. Pronotum was with a large black triangular spot at the base. Scutellum was entirely black. Clear sexual dimorphism was observed in adult of *G. superbus*. The tip of the abdomen in male was rounded inside where genitalia were present. In female the ovipositor was clearly visible when observed ventrally. Adult females were larger in size than adult male. The average length and breadth of female was 4.75 and 2.38 mm, respectively and that of male 4.13 and 1.92 mm, respectively. Multiple mating was observed for this species (Table 1).

3.1 Biology

Incubation period in *G. superbus* was 10 days; nymphal durations 7, 5.2, 5.2, 5.6 and 8.2 days, respectively and total nymphal period was 31.2 days. Pre-oviposition period was 9 days (Table 2). In the current study, male and female developmental periods were almost similar. In the present study, the adult female survived for 30 days and male for 24.8 days. Mean fecundity of 29.4 eggs/female was observed. After a pre-oviposition period, egg laying was observed from the first day after mating and continued till the death of female (Table-2). Per cent hatching was 87. Sex ratio was 1.03:1.00 (female: male) indicating an almost balanced sex ratio in the laboratory and thus as ideal candidate for mass rearing in insectaries.

Table 2: Biology of *Geocoris superbus* reared on *Sitotroga cerealella* eggs and *Phenacoccus solenopsis*.

Stage	Mean ±SEM	Range
Egg period (days)	10±0.31	9-11
Pre-oviposition period (days)	9±0.44	8-10
Duration of nymphal instars (days)		
I	7.0±0.31	6-8
II	5.2±0.37	4-6
III	5.2±0.37	4-6
IV	5.6±0.40	4-6
V	8.2±0.35	7-9
Total nymphal period (days)	31.2±1.11	28-33
Total developmental period (days) (eggs to adult)	-	
Male	41.2±0.58	37-43
Female	41.0±0.89	39-44
Longevity of male (days)	24.8±0.66	23-27
Longevity of female (days)	30.0±0.70	28-32
Eggs/female	29.4±1.72	24-34
Nymphs/female	24.4±3.26	16-34
Per cent eggs hatched	83.0±10.67	50-100
Sex ratio (F:M)	1.03:1.00	

3.2 Feeding potential

Feeding potential of *G. superbus* on *S. cerealella* eggs was studied in order to determine the quantity of host eggs to be provided for successful mass rearing. As is common in geocorids, nymphs and adults pierce the host eggs with their proboscis and suck out the host egg contents. The freshly hatched nymphs of *G. superbus* could feed on bean sap as well as on *S. cerealella* eggs. The mean number of eggs consumed by 1st, 2nd, 3rd, 4th and 5th instars was 39.25, 51.5, 87, 149.25 and 300.75, respectively. The total consumption of eggs during the nymphal period was around 627.75. Among all the nymphal instars, maximum feeding was observed in 5th instar stage especially on the 29th and 30th day when the nymph was about to turn into adult. A lower peak of about 3.25 and 4 eggs consumed per day was observed on first two days of nymphal period, when it initiated feeding on host eggs. The feeding potential of each instar was higher than the previous instar (Table 3, Fig.1).

Table 3: Feeding potential of nymph and adult of *Geocoris superbus* on *Sitotroga cerealella* eggs

Stage	Average no. of eggs^{a} consumed/day/individual	Total no. of eggs^{a} consumed by nymph/adult
1st instar nymph	5.60±0.86	39.25±2.09
2nd instar nymph	10.3±1.10	51.5±5.05
3rd instar nymph	17.4±1.08	87.0±6.23
4th instar nymph	24.9±0.76	149.25±6.87
5th instar nymph	37.6±1.42	300.75±6.63
Total feeding by nymph	-	627.75±8.01
Adult male	47.5±1.19	1176.5±58.06
Adult female	50.5±2.21	1536±35.02

^{a}All values are expressed as Means±SEM

Adult females fed on more *S. cerealella* eggs in comparison to males. Total feeding by one female was 1536 eggs and feeding per day was 50.5 eggs. Adult male fed upon 1176.5 eggs and mean feeding per day was 47.5 eggs (Table-3). Higher feeding rate in female may be due to its higher longevity. Per day feeding was almost similar in both male and female. Since this predator whenever collected was found to be associated with mealybug so keeping this in mind a preliminary study was done on feeding potential of this predator on *Phenacoccus solenopsis* and it was observed that 1st, 2nd, 3rd, 4th, 5th instars and adult can consume 11, 25.5, 34.25, 42.75, 51.75 and 56 crawlers of *Phenacoccus solenopsis* per day, respectively.

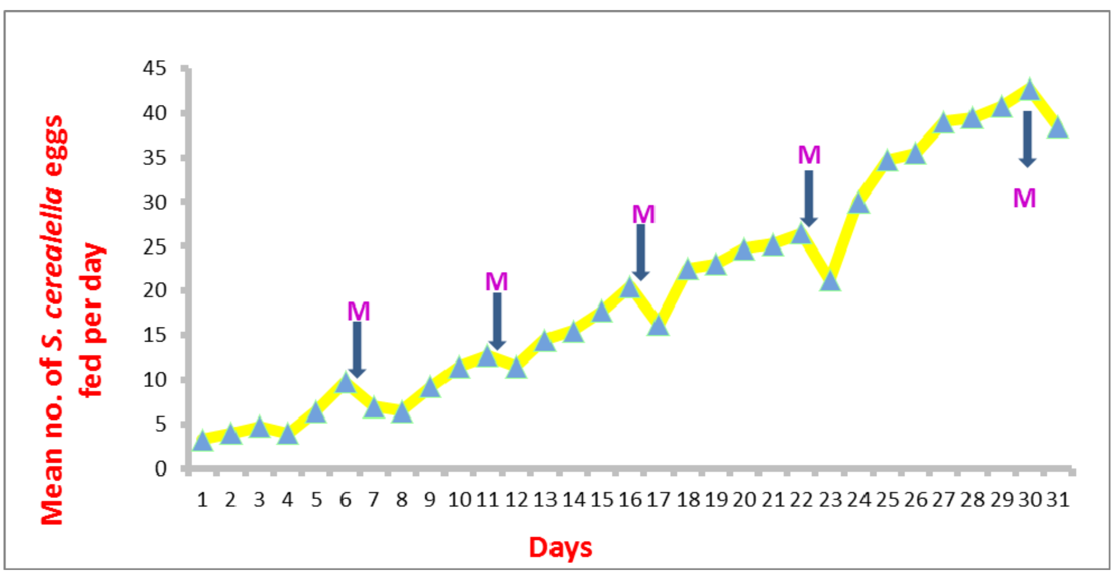

Fig 1: Day-wise feeding potential of nymph of *Geocoris superbus* on *Sitotroga cerealella* eggs * M- Moulting

4. Discussion

So far biology of *G. superbus* has not been studied. This was the first study of *G. superbus*. In India maximum study has been carried out on *G. ochropterus* which is the commonly found geocorids. Earlier it was reported that incubation period of 7.6-9.1 days for *G. ochropterus* when reared on different species of thrips and total developmental duration was observed to vary between 32.7-46.8 days [19]. This result corroborates the present study in which *Sitotroga cerealella* eggs were used. It shows *S. cerealella*, which is highly amenable to rear may be used for mass multiplication of *G. superbus* in laboratory. For other *Geocoris* species, total developmental period of 40 days and 35 days were recorded in case of *G. bullatus* (Say) and *G. pallens*, respectively when reared on aphids, beans and sunflower seeds [2]. In case of *G. lubra*, incubation period of 8.35 days, total developmental period 26.01 days and 70.7% survival to adulthood was observed when fed on *Helicoverpa armigera* (Hu¨bner) eggs [16]. Less mortality was observed in current study where *S. cerealella* eggs were used for rearing. Lepidopteran eggs have high nutritional quality and are considered the rich source of nitrogen content [20]. 1st, 2nd, 3rd, 4th and 5th instar of *G. ochropterus* consumed up to 97.4, 296.4, 423.4, 539.6 and 754 *Scirtothrips dorsalis* Hood, respectively as reported by another report [19]. Total number of *S. dorsalis* consumed by adult male and female of *G. ochropterus* was 1260.2 and 1793.6, respectively, throughout its lifetime. The present results also suggest that voracity increased exponentially with successive immature stages of predator. We also found that female consumed more eggs compared to male as it is attributed to greater size of female, higher longevity and their metabolic demands which is required during egg production [11]. In present study per day feeding on crawlers of mealybug by *G. superbus* was also studied which shows that this predator can be effective predator of *Phenacoccus solenopsis* and further studies need to be done to confirm its feeding potential, and biology on mealybug to exploit this predator for control of mealybug.

The present study indicates that *S. cerealella* eggs can be effectively utilized for continuous rearing of *G. superbus*. Eggs of *Anagasta kuehniella* (Zeller) was found suitable for rearing of *G. punctipes* [20]. In India and outside India, so far nobody has documented *G. superbus* rearing on *S. cerealella* eggs. Our study is the first one to use eggs of *S. cerealella* as prey for rearing of *G. superbus.* It is advantageous to utilize *S. cerealella* as prey as it is amenable to mass rearing.

5. Conclusion

In summary, the present study indicated that *Geocoris superbus* could be reared on eggs of *S. cerealella*, consuming them in high rates. It also presents high fertility, egg viability and high levels of predation. Rearing of *Geocoris* spp. on natural hosts like thrips is very difficult and expensive as it involves maintenance of a whole setup of host insects with their host plants. The present study indicates that *G. superbus* can be reared successfully and continuously on *S. cerealellla* eggs and *Phenacoccus solenopsis* mealybug. The actual cost of production for large scale commercial rearing of *G. superbus* has to be further investigated. This predator can thus be produced in sufficient numbers for field releases in order to target soft bodied insects infesting different crops.

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