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Research Article

Host range, feeding potential and biological attributes of *Micromus igorotus* Banks, a predator of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner

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ABSTRACT: Studies on host range of *Micromus igorotus* Banks, a predator of *Ceratovacuna lanigera* Zehntner indicated that the pupation was higher when aphids belonging to subfamily Hormaphidinae were used as food. Within subfamily Aphidinae, tribe Aphidini was preferred to Macrosiphini. Irrespective of instars of aphid, *Aphis craccivora* Koch was fed in significantly higher numbers than *C. lanigera*. Total feeding potential was also significantly higher on *A. craccivora* of adults. Feeding potential was significantly higher on *Aphis gossypii* Glover and lower on *Pseudoregma bambusicola* (Takahashi) and *C. lanigera*. Pre-oviposition period was significantly longer when adults were reared on *A. gossypii*. The predator laid maximum eggs when fed with *P. bambusicola* while least eggs were laid when *C. lanigera* was provided as prey. Egg and larval periods did not differ significantly on different aphid species, however, pupal period was significantly longer on *A. craccivora* and *A. gossypii* and shortest on *C. lanigera*. This study also provides authentic characters for sex determination of adults of *M. igorotus*.

KEY WORDS: Biology, *Ceratovacuna lanigera*, feeding potential, *Micromus igorotus*, host range

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INTRODUCTION

The Hemerobiidae, the brown lacewings, consists around 550 species, of which the genus *Micromus* Rambur is nearly cosmopolitan and about 100 species are known throughout the World (Oswald, 1993). Different species of *Micromus* are reported from different parts of the World. *Micromus angulatus* (Stephens) was widely studied in countries like Austria, USSR, France and Japan (Sato and Tadaka, 2004; Stelzel and Hassan, 1992; Potemkina and Kovalenko, 1990; Miermont and Canard, 1975), and *M. timidus* Hagen in India (Shantibala *et al*., 1994; Radhakrishnanan and Muraleedharan, 1989; Raychaudhury *et al*., 1981). Intensive surveys on sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner from affected sugarcane areas of south Karnataka resulted in record of its hemerobiid predator, *Micromus igorotus* Banks. This predator has also been recorded from Karnataka (Lingappa *et al*., 2004) and Uttar Pradesh (Singh *et al*., 2009 and 2010). With a view to establish its mass multiplication in the laboratory, its host range, feeding potential and biology on four species of aphids has been studied.

MATERIALS AND METHODS

Host range of larvae: To find out suitable prey for laboratory rearing of *M. igorotus*, 20 hosts were screened for their suitability in sustaining larval growth. To compare the performance of larvae on different groups of aphids, 12 species of aphids belonging to three tribes (Aphidini, Macrosiphini and Cerataphidini) within two subfamilies (Aphidinae and Hormaphidinae) were selected. Out of these aphid species, eight belonged to subfamily Aphidinae *viz., Aphis gossypii* Glover [on *Gossypium hirsutum*], *A. spiraecola* Patch [on *Arelia* sp.], *A. craccivora* Koch [on *Vigna unguiculata*], *Toxoptera aurantii* (Boyer de Fonscolombe) [on *Citrus* sp.], *Uroleucon compositae* (Theobald) [on *Carthamus tinctorius*], *Pentalonia nigronervosa* Coquerel [on *Alpinia* sp.], *Myzus persicae* (Sulzer) [on *Brassica juncea*] and *Brevicoryne brassicae* (Linnaeus) [on *Brassica oleracia* var *Capitata*] and four to subfamily Hormaphi-dinae *viz*., *Pseudoregma bambucicola* (Takahashi), *Astegopteryx bambucifoliae* (Takahashi), *A. bambusae* (Buckton) [all on *Bambusa* sp.] and *C. lanigera* [on *Sacchrum officinarum*]. Remaining eight preys were, two commonly

used Lepidopteran factitious laboratory prey *viz*., eggs of *Corcyra cephalonica* Stainton and *Sitotroga cerealella* (Olivier) and five belonged to Hemiptera *viz*., *Ferrisia virgata* (Cockerel), *Planococcus citri* (Risso), *Maconellicoccus hirsutus* (Green), *Aleurodicus dispersus* Russell, *Bemisia tabaci* Gennadius and *Heteropsylla cubana* (Crawford). Aphid infested plant parts were directly brought from the field and bouquets were made. These bouquets were kept in acrylic sheet cages (30 x 30 x 30 cm) and twenty-five larvae of *M. igorotus* were released on each species of aphids. There were four replications. Similar procedure was followed for evaluating *A. dispersus*, *B. tabaci* and *H. cubana* as host. Mealybugs were reared on pumpkin and fifty larvae were released on pumpkins infested with each species. There were two replications. Eggs of *C. cephalonica* and *S. cerealella* were lab reared following the standard procedure. One cc of eggs of each prey were kept separately in an insulin vial and single larva of *M. igorotus* was released. There were 50 vials for each replication and there were two replications. Thus, a total of 100 larvae were reared on all the hosts. Percent pupation on all these prey was determined. Data thus obtained were analysed by using Duncan's Multiple Range Test. Data obtained on prey on which the larvae could not survive and pupate were not included for statistical analysis.

Larval feeding on *A. craccivora* and *C. lanigera*: *Aphis craccivora* was reared on the seedlings of cowpea sown in the polyurethane containers (9.5 x 9.5 x 4 cm as per methodology developed by Joshi *et al*. 1998). Adult females were allowed to lay young ones on the seedlings. The seedlings with first, second, third and fourth instars were removed from the polyurethane containers and were kept in a plastic containers with ventilated lids measuring 6.25 cm (height) x 19.00 cm (diameter). The uprooted seedling roots were covered with moist absorbent cotton to avoid their drying. The larva was released immediately after hatching and pre-release aphids and post-feeding aphis counts were taken. Feeding potential on each instar of aphid was calculated based on 30 larvae of *M. igorotus*. The dead larvae were replaced with the newly hatched ones and thus the equal replications were maintained. Similar procedure was followed when *C. lanigera* was used as a prey. Sugarcane leaf bits with colony of aphid of desired instars were cut and ends of the leaf bit were covered with absorbent cotton and wet sponge. Data thus obtained were analysed by two way factorial RBD.

Sex determination of adults: After emergence the adults were allowed to expand and harden their wings and appendages for 24 hours in spacious plastic containers. The adults were carefully observed under SZ-PT Olympus B 202 microscope for studying male and female characters.

Pre-ovipostion period and fecundity of *M. igorotus*: Pre-oviposition, adult feeding potential and fecundity were studied using four aphid species *viz*., *A. gossypii*, *A. craccivora*, *P. bambusicola* and *C. lanigera*. The aphid species were selected on the basis of good larval performance. For studying pre-oviposition period and fecundity of *M. igorotus*, adults were obtained by rearing larvae on the same species of aphids on which the adults were supposed to be evaluated for their feeding potential. Host plant parts infested with the aphid species *viz*., *A. gossypii* (on cotton), *A. craccivora* (on cowpea), *P. bambusicola* (on bamboo) and *C. lanigera* (on sugarcane) were kept in a Pearlpet® container of half-liter capacity and equal number of male and females (five pairs) were released in each containers. Honey (50%) soaked in cotton swab was provided as an additional source of carbohydrate. Fibrous material was provided for egg laying. The period from adult emergence and initiation of oviposition was considered as pre-oviposition period. The eggs laid on fibrous material were dislodged and were counted to work out fecundity. The total number of eggs obtained from each container till death of the adults were counted and divided by the number of females to get fecundity of *M. igorotus*. Data thus collected were subjected to simple RBD analysis.

Larval feeding potential on *C. lanigera* and *A. craccivora*: Instar wise feeding potential of *M. igorotus* was studied by using *A. craccivora* and *C. lanigera*. *A. craccivora* was reared on the seedlings of cowpea and *C. lanigera* was multiplied on sugarcane plants sown in NBAII campus. Plastic containers (6.25cm H x 19.00 cm D) with ventilated lids were used for experiments. A single larva immediately after hatching was released on the pre-counted aphids and was allowed to feed till it enters the next instar. Post release count gave the aphids fed by each instar. In this experiment a mixture of all the instars of aphids were provided for feeding. Data thus obtained were subjected to statistical analysis by using simple RBD. As only instar wise feeding potential was analysed in this experiment, separate experiments were conducted to work out total larval feeding by following the same procedure.

Biological attributes on four species of aphids: Biology of *M. igorotus* was studied on four aphid species *viz*., *A. gossypii* (on cotton), *A. craccivora* (on cowpea), *P. bambusicola* (on bamboo) and *C. lanigera* (on sugarcane) by keeping them in a Pearl pet container. For

study, *M. igorotus* adults were released on each aphid species. Eggs laid were kept separately for studying egg period. Larvae resulting from these eggs were released on respective aphid species and period up to pupation was recorded as larval period. Similarly, pupae were removed from the plant parts or the base of the containers and were kept separately for adult emergence. Pupal period and adult longevity were recorded for all the four prey species. Data collected was subjected to single factor RBD analysis.

RESULTS AND DISCUSSION

Host range of larvae: The larvae could not survive on any of the mealy bugs, whiteflies, psyllid and eggs of lepidopterans but they survived on all aphid species and pupated (Table 1). Percent pupation ranged from 45.19 (on *B. brassicae*) to 93.18 (on *P. bambusicola*). Pupation was higher on aphids belonging to subfamily Hormaphidinae. Coincidently, the natural host of *M. igorotus* belongs to the same subfamily. Within subfamily Aphidinae, tribe Aphidini (84.76% population) was preferred over Macrosiphini (73.05% pupation). Results thus indicated that for larval rearing, aphids belonging to Hormaphidinae can be used, however, these aphids are specific to *Bambusa* sp. and they could not be reared in the laboratory, and hence the second best option can be aphid species belonging to Aphidini tribe. The techniques for multiplication of *A. craccivora* throughout the year have been developed (Joshi *et al*., 1998). Earlier studies on host range of this predator have been conducted by Mulimani *et al.* (2007). Some of the aphid hosts chosen by them for the study were not identified even up to genus level and only the common name was cited *i.e*. Hibiscus aphid, which can be either *A. gossypii* Glover or *Toxoptera odinae* (van der Goot). The other prey *Uroleucon carthami* (Theobald) reported by them does not occur in India and it could be *U. compositae* (Theobald). Common English name of *Rhopalosiphum maidis* (Fitch) was given as sorghum aphid which should be corn leaf aphid. *Myzus nicotianae* (Blackman) is not valid species and has been reverted back to *M. persicae* (Sulzer). No species with name *Macrosiphum rosaeformis* D. exists. It should be either *Macrosiphum rosae* (Linnaeus) or *Sitobion rosaeformis* (Das). No authority has been given for *Schizaphis graminum* (Rondani). This indicates that the host insect chosen were not identified properly and hence study had no proper scientific base.

Larval feeding potential on different instars of *A. craccivora* and *C. lanigera*: Irrespective of instars, *A. craccivora* was fed in significantly higher numbers

Table 1. Percent pupation of *Micromus igorotus* larvae on different aphid species

Aphid species (Family: Subfamily: Tribe)	Per cent pupation*	Average percent pupation within group
Aphididae: Aphidinae: Aphidini		
Aphis gossypii Glover	89.22[b]	84.76
Aphis spiraecola Patch	82.38[c]	
Aphis craccivora Koch	87.90[b]	
Toxoptera aurantii (Boyer de Fonscolombe)	79.52[d]	
Aphididae: Aphidinae: Macrosiphini		
Uroleucon compositae (Theobald)	84.09[c]	73.05
Pentalonia nigronervosa Coquerel	83.96[c]	
Brevicoryne brassicae (Linnaeus)	45.19[e]	
Myzus persicae (Sulzer)	78.98[d]	
Aphididae: Hormaphidinae: Cerataphidinae		
Pseudoregma bambusicola (Takahashi)	93.18[a]	87.95
Astegopteryx bambucifoliae (Takahashi)	87.71[b]	
Astegopteryx bambusae (Buckton)	84.22[c]	
Ceratovacuna lanigera Zehntner	86.67[b]	

* Unplanned pair comparison made by DMRT

Table 2. Larval feeding potential of *Micromus igorotus* on different instars of *Aphis craccivora* and *Ceratovacuna lanigera*

Instars of aphid species	Feeding potential / larva on		Instar mean
	Aphis craccivora (No. ± SD)	*Ceratovacuna lanigera* (No. ± SD)	
1st instar	769.8 ± 40.83	606.7 ± 66.91	688.25[a]
2nd instar	707.5 ± 57.15	559.9 ± 46.06	633.70[b]
3rd instar	652.9 ± 84.49	493.7 ± 47.21	573.30[c]
4th instar	591.2 ± 67.04	381.1 ± 51.98	486.15[d]
Aphid species mean	680.35[a]	510.35[b]	

CD $P \leq 0.05$ A = 26.45, B = 37.40, AXB = N.S.

(680.35 aphids / larva) as compared to *C. lanigera* (510.35 aphids / larva) (Table 2). Regardless of species, the first instars were fed in maximum numbers (688.25 aphids / larva), whereas, fourth instars were fed the least (486.15 aphids/larva). In *A. craccivora*, first instar was fed by 30.22% more as compared to 4th instar. Second and third instars were fed 19.67 and 10.44% more, respectively than the 4th instar. First, second and third instars of *C. lanigera* were fed 59.18, 46.91 and 29.18% more than 4th instar. As first instars were fed in higher numbers, the predator is likely to work well at early infestation levels, a situation where first instars are expected to be more in numbers as compared to other instars. No studies on feeding potential of this predator on different instars of aphid are available for comparison.

Sex determination of adults: Microscopic observations of adults indicated that the last abdominal tergite of male is divided into two plates. Each plate possesses long slender, posteriorly projecting cuticular process. These processes cross each other behind the body. Female does not exhibit these characters. In addition to this ectoproct was larger and pointed in male whereas rounded, short and blunt in female. Dr. J. D. Oswald, Texas A&M University, Texas, later confirmed these observations.

Adult feeding potential, pre-ovipostion period and fecundity: Pre-ovipostion period ranged from 4.3 to 6.3 days on different aphid species (Table 5). It was significantly longer when adults were reared on *A. gossypii*; however there was no significant difference in pre-oviposition period when adults were fed on the other species.

Micromus igorotus laid the maximum eggs when reared on *P. bambusicola* (899.9 eggs/female) which was the least when *C. lanigera* was fed (690.25 eggs/female). Here, probably, the longevity of adults on these aphid species have significant role to play. It was lowest when fed on *C. lanigera* because, the adults were found entangled into mealy mass of *C. lanigera* at the base of rearing containers. These entangled immobile adults were found to be attacked by the soldiers. This explains the lowest longevity and fecundity on its natural host. There was no significant difference in the fecundity obtained on *A. gossypii* (715.69 eggs/female) and *A. craccivora* (762.25 eggs/females). Even though it laid maximum eggs when fed with *P. bambusicola* (899.90 eggs/female), feeding potential was least (561.1 aphids/adult) on this species. On the other hand, *A. gossypii*, was fed in maximum numbers (2019.1/adult), but, yielded least eggs. Nutritional quality of the prey and its size probably affected fecundity and biomass of prey. *A. gossypii*, which is smallest in size, was fed in larger numbers, while, *P. bambusicola,* largest amongst the species provided, was fed in least numbers. The predators laid 35.5% more eggs when *P. bambasicola* was used as prey as compared to *C. langiera.* Per cent increase in fecundity was 12.19 and 10.87% on *A. carccivora* and *A. gossypii,* respectively, as compared to *C. lanigera.* Fecundity on different aphid species reported by Mulimani *et al.* (2007a) was much less than our study. This was perhaps because they used adult size as a parameter for sexing and pairing mates which can possibly led to inappropriate sexing and that might have led to wrong calculation of number of eggs per female. Accurate sex determination as followed in our study gave most appropriate determination of fecundity.

Instar-wise feeding potential on *C. lanigera* and *A. cracivora*: First, Second and third instar larvae of *M. igorotus* fed on 63.80, 112.70 and 283.00 individuals of *C. lanigera* (Table 3). The corresponding values on *A. craccivora* were 41.60, 115.00 and 354.70 aphids. This shows that consumptions increased with advancement in age of the larvae on both the preys. Feeding potential

Table 3. Instar wise larval feeding potential of *Micromus igorotus* on two species of aphids

Instars of *Micromus igorotus*	Feeding potential (No. ± SD/ instar)	
	Aphis craccivora	*Ceratovacuna lanigera*
1st instar	63.80 ± 3.77[c] (13.88 %)	41.60 ± 1.51[c] (8.13 %)
2nd instar	112.70 ± 0.49[b] (24.53 %)	115.00 ± 12.03[b] (22.49 %)
3rd instar	283.00 ± 52.18[a] (61.59 %)	354.70 ± 26.00[a] (69.37 %)
CD $P \leq 0.05$	30.04	41.15

Table 4. Duration of different life stages of *Micromus igorotus* on four aphid species

Aphid species	Biological attributes			
	Incubation (Days)	Larval period (Days)	Pupal period (Days)	Adult longevity (Days)
Aphis craccivora	4.00 ± 0.82	7.00 ± 1.41	7.90 ± 1.19[a]	41.30 ± 2.62[c]
Pseudoregma bambusicola	3.70 ± 0.48	7.30 ± 1.16	6.90 ± 0.88[ab]	44.00 ± 2.71[b]
Aphis gossypii	4.00 ± 0.82	7.50 ± 1.18	7.10 ± 0.74[a]	46.90 ± 3.03[a]
Ceratovacuna lanigera	3.90 ± 0.74	6.70 ± 1.16	6.00 ± 0.94[c]	34.50 ± 3.02[d]
CD $P \leq 0.05$	N.S.	N.S.	0.910	2.77

Table 5. Adult feeding potential, pre-oviposition and fecundity of *Micromus igorotus* on four aphid species.

Aphid species	Feeding potential(Number/adult)	Pre-oviposition period	Fecundity (Eggs/female)
Aphis gossypii	2019.10 ± 247.39[a]	6.30 ± 1.42[a]	715.69 ± 98.19[b]
Aphis craccivora	1695.30 ± 106.55[b]	5.20 ± 1.23[b]	762.20 ± 57.90[b]
Pseudoregma bambusicola	561.10 ± 82.85[c]	4.80 ± 0.79[b]	899.90 ± 54.16[a]
Ceratovacuna lanigera	649.00 ± 114.48[c]	4.30 ± 0.82[b]	690.25 ± 70.12[c]
CD $P \leq 0.05$	140.37	0.949	63.04

increased gradually with the last instar feeding on maximum number of aphids. When *C. lanigera* was used as host, 61.59% of total aphids consumed were fed by the last instar while in case of *A. cracivora,* 69.37% of total aphids consumed were fed by the third instar.

Studies on total feeding potential of *M. igorotus* larvae indicated that there was significant difference in number of aphids fed when *A. craccivora* and *C. langiera* were provided as prey (Table 4). Feeding potential was significantly higher on *A. craccivora* (501.33 aphids per larva) than on *C. lanigera* (451.00 aphids/larva). Our studies on feeding potential on these two species of aphids corroborate with the study by Mulimani *et al.* (2007b).

Biological parameters of *M. igorotus* on four species of aphids: Incubation of eggs of *M. igorotus* varied from 3.70 to 4.00 days and it did not differ significantly when adults were fed with different species of aphids (Table 4). Similarly, there was no significant difference in larval period when different aphids were provided as prey. It varied from 6.7 to 7.5 days. Pupal period, however varied significantly, being longer on *A. craccivora* (7.00 days) and *A. gossgpii* (7.10 days) and shorter on *C. lanigera* (6.00 days). Total development was completed in 18.9, 17.9, 18.6 and 16.6 days on *A. craccivora*, *P. bambucicola*, *A. gossypii* and *C. lanigera*, respectively. The values recorded in the present study did not differ much from Mulimani *et al*. (2007b). However, they have

Table 6. Total larval feeding potential of *Micromus igorotus* on *A. craccivora* and *C. lanigera*

Aphid species	Feeding potential (No. of aphids ± SD)
Aphis craccivora	506.33 ± 28.23[a]
Ceratovacuna lanigera	451.00 ± 58.95[b]
CD $P \leq 0.05$	34.33

not included *P. bambusicola* in their study as host, which belongs to the same subfamily as *C. lanigera*.

It can be concluded that *M. igorotus* accepted all aphid species as prey, but, did not accept non-aphid hosts. The pupation was higher when aphids belonging to subfamily Hormaphidinae were used as prey and tribe Aphidini was preferred to Macrosiphini. Egg and larval periods did not differ on different aphid species, however, pupal period was longer on *A. gossypii* and *A. craccivora* and shorter on *C. lanigera.* Per cent pupation, per cent adult emergence, adult longevity and fecundity were highest on *P. bambusicola* (which cannot be reared in the laboratory). The third better option i.e. *A. craccivora* (for which multiplication techniques available) can be used for production of *M. igorotus*.

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