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Functional response of the ladybird, *Cydonia vicina nilotica* to cowpea aphid, *Aphis craccivora* in the laboratory

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Abstract The functional response of *Cydonia vicina nilotica* Muls. (Coleoptera: Coccinellidae) to six densities of *Aphis craccivora* Koch (Homoptera: Aphididae) nymphs on broad bean (*Vicia faba* Linn.) was investigated in the laboratory. A linear relationship between the rate of consumption and prey density was observed with r^2 values between 0.58 and 0.97. Plotting prey density against prey killed by four larval instars, and adult males and females of *C. vicina nilotica* fit well with the type II model of Holling's disc equation. Adult females consumed the highest number of prey, followed by fourth instars and adult males. Based on the functional response data, the model predicts a maximum of 144.9, 116.3, 86.2, 80.0, 72.5 and 20.0 nymphs to be consumed per day by an individual adult female, fourth instar, adult male, third, second and first instars, respectively. The differences in the responses of the predator to aphid densities are discussed.

Key word *Aphis craccivora*, coccinellids, *Cydonia vicina nilotica*, functional response, predation
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Introduction

It is well known that functional response of a predator is a key factor regulating population dynamics of predator-prey systems. The functional response describes the relationship between an individual predator's consumption rate and prey density (Solomon, 1949) and therefore, can predict the maximum number of prey that can be consumed by a given predator per day. Holling (1959) classified functional responses as types I, II and III, and the functional response of most beneficial arthropods is either type II or type III (Luck, 1984).

Aphis craccivora Koch (Homoptera: Aphididae) is one of the most important insect pests attacking broad bean, lentil, sugar beet, pepper, tomato and other crops in Egypt (Abd El-Ghaffar, 1986; Megahed & Hashem, 2004). Its population is subjected to biological regulation by a large number of natural enemies, including predators and parasitoids. *Cydonia vicina nilotica* Mulsant is a native and widespread aphidophagous coccinellid predator in Egypt (Ghanim & El-Adl, 1987). El-Batran *et al.* (1996) reported that *C. vicina nilotica* is a very voracious predator and consumes approximately 191, 475, and 500 *Brevicoryne brassicae* (Linn.) individuals in the whole larval period, male and female adult stages, respectively. Recently, we observed that its population was steadily increasing in broad bean fields (Mandour, Unpublished). Numerous individuals of *C. vicina nilotica* occur on the plants with low or moderate densities of *A. craccivora*

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compared to those with higher aphid densities, thereby indicating that *C. vicina nilotica* avoids attacking plants with high density of *A. craccivora*. However, this inference needs to be substantiated by empirical evidence, such as investigation on its functional response. Moreover, both second and third instar larvae showed high predation potentials against *A. craccivora* (Mandour, unpublished data). Therefore, we investigated the functional responses of all predaceous stages of this ladybird along with the effect of different densities of *A. craccivora* on broad bean plants.

Materials and methods

Stock maintenance

Cydonia vicina nilotica (35 adults) collected from broad bean (*Vicia faba* Linn.) fields infested with *A. craccivora* were reared on *A. craccivora* on broad bean plants in plastic cages (30 cm wide × 30 cm long × 20 cm high) under laboratory conditions (25 ± 2℃, 60% ± 10% RH, and 14:10 h L: D) . A colony of *A. craccivora* was also maintained on broad bean plants cultivated in small pots (15 cm high × 10 cm diameter) at 22 ± 5℃, 50% ± 20% RH and 14:10 h (L: D) in a glasshouse (4 m × 6 m × 5 m). The experiments were conducted under abiotic conditions similar to that for stock maintenance.

Prey consumption by larvae and adults

Cydonia vicina nilotica larvae (4 h post-molting) were collected from the colony and starved for 4 h in clean plastic vials (7 cm diameter × 2 cm deep). Adult males and females (7−10 days old) were collected in plastic jars (20 cm long × 10 cm diameter), provided with *A. craccivora* on broad bean plants and kept in cohort for mating. After 24 h, adults were separated and sexed according to the size and color (male is darker in color and smaller in size than female) and starved for 24 h before being used. Predation was assessed by placing a single larva/adult in an experimental arena consisting of a glass tube (10 cm long × 3 cm diameter) containing a small broad bean branch with three leaflets. To avoid drought, the bottom end of the broad bean stem was wrapped in a water-saturated cotton ball.

To avoid reproduction of aphids during the experiment, second to third instars were used. As predation potential for ladybird larva increases as larva proceeds to the next stage, prey densities were increased for later instars and adult stages. Therefore, six prey densities of *A. craccivora* were evaluated: 10, 20, 30, 40, 50 and 60 nymphs for the first instar; 20, 40, 60, 80, 100 and 120 nymphs for the second instar; 25, 50, 75, 100, 125 and 150 nymphs for the third instar; 30, 60, 90, 120, 150 and 180 nymphs for the fourth instar; and 50, 75, 100, 125, 150 and 200 nymphs for adult males and females, respectively. *A. craccivora* nymphs were gently transferred to each experimental arena using a fine camel-hair brush putting them on the broad bean branch described above. After 24 h, all dead and living aphids were recorded.

Data analyses

The relationships between mean rate of consumption (prey consumed/prey offered × 100) by adult males, females and different larval instars in relation to prey density were analyzed using a general regression procedure (PROC REG, SAS Institute, 2000). Holling curvilinear type II equation (Holling, 1959) was used to fit the data for functional response. In this model, the number of prey consumed (Na) is a function of prey density (N) as follows:

$$\mathrm{Na} = (\acute{a}T_t\ \mathrm{N}) / (1 + \acute{a}T_h\ \mathrm{N}),$$

where á is the rate of attack (discovery) of the prey, T_t is the total time available (1 d or 24 h in this experiment), and T_h is the handling time for one prey.

Results

The differences in the prey consumption at various prey densities within a developmental stage of *C. vicina nilotica* were significant for first ($F = 6.70$; df = 5, 54; $P < 0.000\,1$), second ($F = 11.98$; df = 5, 54; $P < 0.000\,1$), third ($F = 11.65$; df = 5, 54; $P < 0.000\,1$) and fourth instars ($F = 8.67$; df = 5, 54; $P < 0.000\,1$), adult males ($F = 4.71$; df = 5, 54; $P < 0.001\,2$) and females ($F = 15.02$; df = 5, 54; $P < 0.000\,1$). The percentage of prey consumed by each predatory stage is negatively correlated with the prey densities offered (Fig. 1) with subsequent r^2 values being highest (0.99) for 3rd instars and lowest (0.61) for adult females (Table 1). The rate of prey consumption declined with the increasing prey density for predatory stages, suggesting that these stages exhibit a type II functional response (Fig. 2).

The third instars showed the highest (1.32) rate of attack (Table 1). However, the second instars exhibited the lowest (0.55) rate of attack. Hand-ling time decreased as predatory larva proceeded to the next stage, and the adult females had the shortest handling time (9.94 min). Subsequently, the model predicts a maximum consumption of 20.0, 72.5, 80. 0, 116.3, 86.2 and 144.9 *A. craccivora* nymphs by first, second, third and fourth instars, adult males and females, respectively in 24 hours (Table 1).

Table 1 Type II functional response parameters of *C. vicina nilotica* at different densities of *A. craccivora*.

Stage/instar	*n*	á ± SE	T_h ± SE (min)	T_t / T_h	r^2
First instar	10	0.61 ± 0.16	0.0501 ± 0.0106 (72.14)	19.96	0.86
Second instar	10	0.55 ± 0.11	0.0138 ± 0.0039 (19.87)	72.47	0.70
Third instar	10	1.32 ± 0.13	0.0125 ± 0.0008 (18.00)	80.00	0.99
Fourth instar	10	0.92 ± 0.20	0.0086 ± 0.0019 (12.38)	116.32	0.86
Male	10	1.10 ± 0.68	0.0116 ± 0.0046 (16.70)	86.23	0.64
Female	10	0.96 ± 0.28	0.0069 ± 0.0022 (9.94)	144.87	0.61

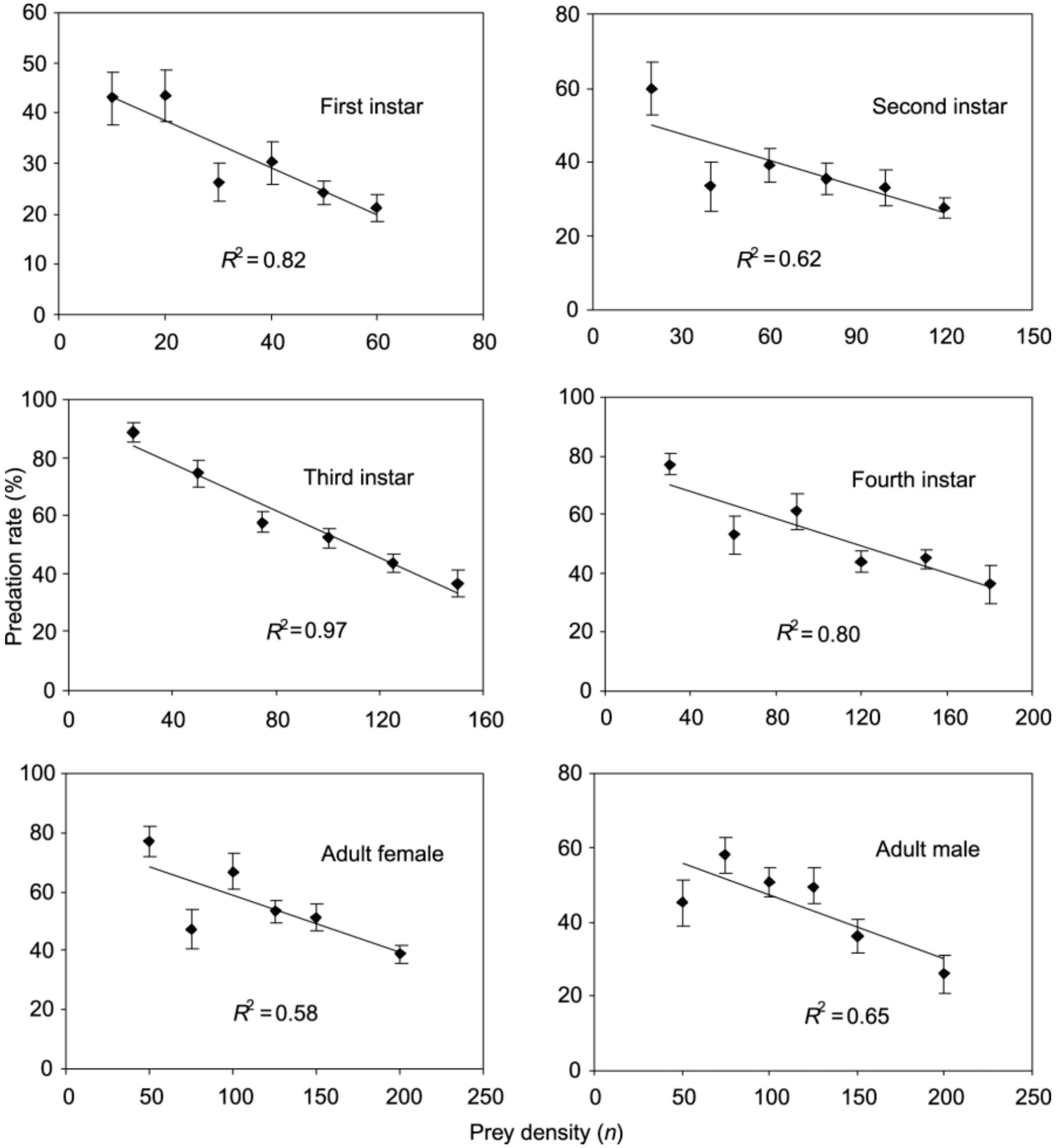

Fig. 1 Percent predation of *Cydonia vicina nilotica* to *Aphis craccivora* on broad bean in glass vial arenas. Points show average number of aphids eaten or killed by *C. vicina nilotica* at each level of prey availability. Error bars show standard errors.

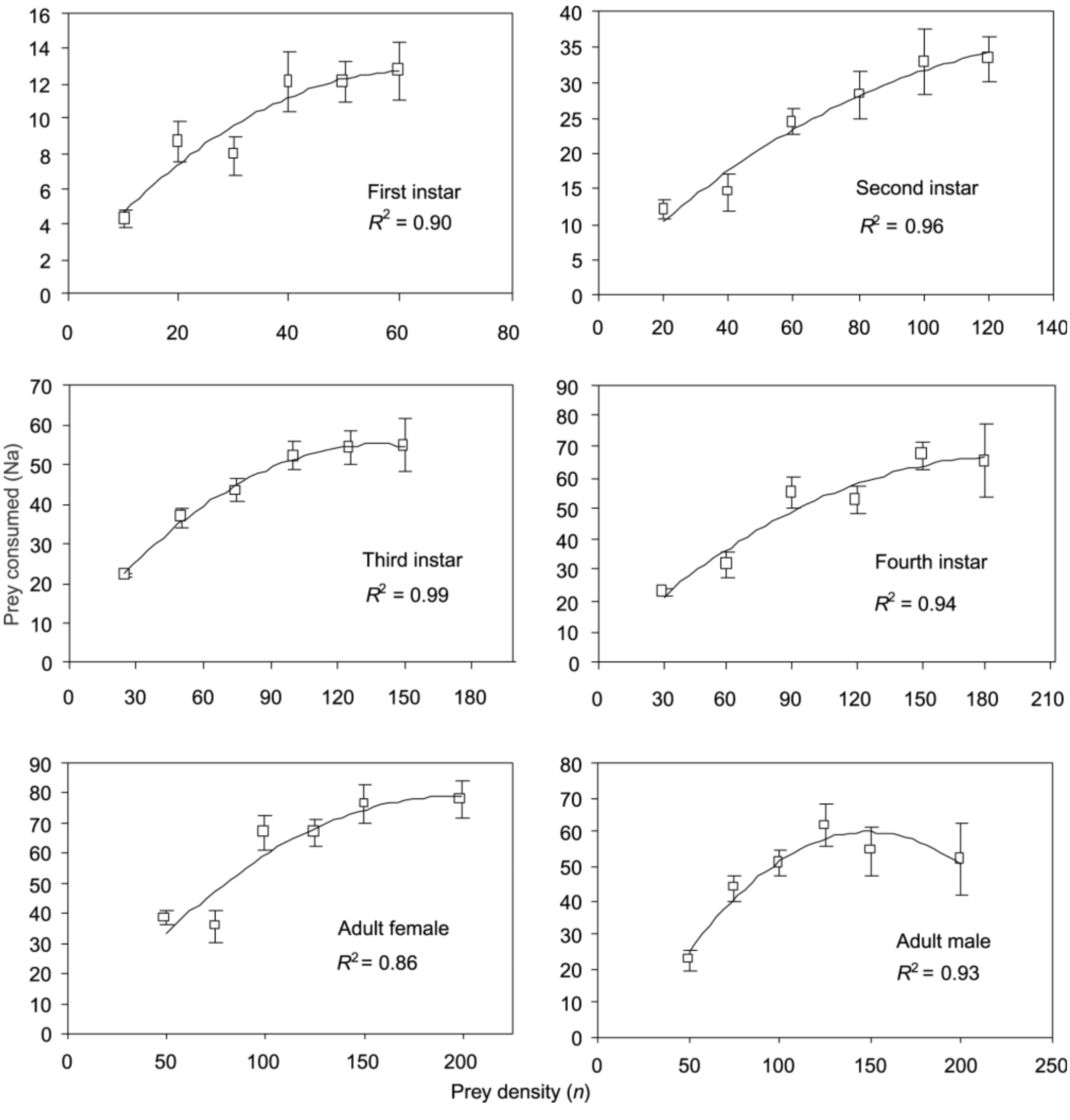

Fig. 2 Functional response of *Cydonia vicina nilotica* to *Aphis craccivora* in glass vial arenas. Points show average number of aphids eaten or killed by *C. vicina nilotica* at each level of prey availability. Error bars show standard errors. The line shows the Holling's model for a type II functional response.

Discussion

The data indicate that all stages of *C. vicina nilotica* tested, exhibited typical type II functional response (Fig. 2). Similar response was earlier reported for other coccinellids, that is, *Propylea dissecta* (Mulsant) (Pervez & Omkar, 2005), *Nephaspis oculatus* (Blatchley) (Liu & Stansly, 2002), *Stethorus punctillum* (Weise) (Rott &

Ponsonby, 2000), or even other non-coccinellid predators such as *Amblyseius longispinosus* (Evans) (Zhang *et al*., 1999) and *Orius albidipennis* (Reuter) (Gitnoga *et al*., 2002).

The relative rate of prey consumption by *C. vicina nilotica* was higher at lower densities, which indicates that this predator would be more effective at controlling the *A. craccivora* population at lower densities. The failure of *C. vicina nilotica* and other coccinellids in controlling the aphid at higher population densities could be attributed to: (i) the low oviposition rate of *C. vicina nilotica* at these densities, which reflects the desire to reduce intraguild competition and leads to lower chances of establishment of a viable colony of the predator at higher prey densities (Mandour, unpublished); (ii) aphids excreted droplets, alarm pheromone, which affects the searching behavior of the predators; and (iii) a high density of aphids is mostly accompanied by a great amount of honeydew, which is used by other coccinellids as contact kairomone (Meiracker *et al*., 1990), and is expected to preclude the searching behavior and reduce the searching efficiency of the predators. More importantly, a high rate of prey consumption is not a feature of aphidophagous coccinellids (Pervez & Omkar, 2003) that leads to the failure of aphid biological control programs using only predatory coccinellids. Therefore, for consideration of biocontrol of *A. craccivora*, the coccinellids have to be released early before the aphids reach high densities.

The elevated functional response curve of adult females over that of the adult males indicates the possibility of delayed satiation (Mills, 1982), faster digestion (Pervez & Omkar, 2005), larger body size than males; hence greater food requirement and higher nutritional demands, particularly for egg formation.

Based on the handling time (the time taken by a predator in locating, capturing, subduing, killing and digesting one prey), attack rate, and number of prey consumed, it is obvious that besides the adult stage, the third and fourth instars are effective predatory stages in attacking the aphids, and are the suitable stages for field release. Similarly, the same stages yielded the highest functional response in *Nephaspis oculatus* (Liu & Stansly, 2002) and *Stethorus gilvifrons* (Mulsant) (El-Basha & Mandour, 2005).

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