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Bülent Yaşar · Şenay Özger

Development, feeding and reproduction responses of *Adalia fasciatopunctata revelierei* (Mulsant) (Coleoptera: Coccinellidae) to *Hyalopterus pruni* (Geoffroy) (Homoptera: Aphididae)

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Abstract This study was carried out to determine the development, survival and reproduction responses of *Adalia fasciatopunctata revelierei* (Mulsant) (Coleoptera: Coccinellidae) feeding on *Hyalopterus pruni* (Geoffroy) (Homoptera: Aphididae), using 20, 40, 80, 160 and 250 prey densities. All experiments were conducted at 25±1°C, 60±5% relative humidity, 16:8 light:dark under laboratory conditions. The average daily prey consumption of *A. fasciatopunctata revelierei* immatures and adults increased with increasing prey densities. Predation was not different for the larval stages at 80, 160 and 250 prey densities. The longevities of adult females were 35.67, 35.33, 49.00, 58.33 and 57.16 days when 20, 40, 80, 160 and 250 *H. pruni* were provided, respectively. The mean daily and total fecundity of *A. fasciatopunctata revelierei* increased with increasing prey densities. Females of *A. fasciatopunctata revelierei* feeding on *H. pruni* laid 89 eggs at 20 prey density and 301.67 eggs at 160 prey density. The search rate of females was higher than that of all larval instars; and the search rate of the fourth-instar larvae was higher than that of younger instars. Handling time decreased with development from larval stages to adult.

Keywords Aphididae · Search rate · Coccinellidae · Handling time · Numerical response · Functional response

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B. Yaşar (✉) · Ş. Özger
Yüzüncü Yıl Üniversitesi,
Ziraat Fakültesi, Bitki Koruma Bölümü,
Van, 65080, Turkey
E-mail: bulentyasar99@hotmail.com
Tel.: +90-432-2251390
Fax: +90-432-2251104

Introduction

The mealy plum aphid, *Hyalopterus pruni* (Geoffroy) is one of the most important pests of peach, plum and apricot in eastern Turkey (Blackman and Eastop 1984; Toros et al. 1996); and reed (*Pragmites australis* Cav.) serves as a secondary host for this aphid species, which has a heteroecious life cycle (Dixon 1987). There are many natural enemies of *H. pruni*, both around the world and in Turkey (Basky 1982; Hodek 1973; Frazer 1988; Öncüer 1991; Iperti 1999). Among them, *Adalia fasciatopunctata revelierei* (Coleoptera: Coccinellidae) appears to be one of the most important natural enemies of *H. pruni* (and *Aphis pomi*, *Dysaphis pyri* and *Callaphis juglandis* in Van Province, Turkey; Erol and Yaşar 1996; Yaşar et al. 1999). Moreover, *Aphis pruni*, *Brachycaudus helichrysi*, *Myzus cerasi*, *M. lyrthri*, *Periphillus turticornis*, *Rhopalosiphum maidis* and *R. padi* are also available prey for *Adalia fasciatopunctata revelierei* in Turkey (Öncüer 1991). In Turkey, *Adonia variegata*, *Synharmonia conglobata* (Yaşar and Özgökçe 1994), *Symnus apetzi* (Kaydan and Yaşar 1999), *S. subvillosus* (Atlıhan et al. 1999), *Adalia bipunctata* (Özgen and Yaşar 1999) and *Exochomus nigramaculatus* (Kasap and Yaşar 1996) are also known predators of *H. pruni*.

Functional response has received much attention in the entomological and ecological literature (e.g. Holling 1959; Rogers 1972; Wiedenmann and O'Neil 1991; Fan and Petitt 1994; Heimpel and Hough-Goldstein 1994; Williams and Juliano 1996; Munyaneza and Obrycki 1997; Gitonga et al. 2002; Kumar et al. 2002). Several types of functional responses in relation to prey density have been described. These include a linear increase (type I), an increase decelerating to a plateau (type II), a sigmoid increase (type III) and a dome-shaped response (type IV).

Many arthropod predators exhibit a type II functional response, which is characterized by a predation rate that is limited only by handling time. Functional response refers to the change in the number of prey consumed by a predator per unit time in relation to prey density.

Virtually no research has been conducted to determine the development time and functional response of all predatory stages (larval, adult) of *A. fasciatopunctata revelierei* to *H. pruni*. So, this work was aimed at determining the consumption rate (larval stages, adult females), development time and fecundity of *A. fasciatopunctata revelierei* at different densities of mealy plum aphid (*H. pruni*) in laboratory conditions.

Materials and methods

The initial population of mealy plum aphid, *H. pruni* (Geoffroy), was collected from reeds (*Pragmites australis* Cav.), and the population of *A. fasciatopunctata revelierei* (Mulsant) was collected from plum and apricot orchards in Van, Turkey. Experiments were conducted at 25 ± 1°C, 60 ± 5% relative humidity, 16:8 light:dark under laboratory conditions.

Experiments were initiated after rearing one generation of *A. fasciatopunctata revelierei* under laboratory conditions and were carried out with densities of 20, 40, 80, 160 and 250 mealy plum aphids in Petri dishes [8 cm diam., total floor/wall area ($A = 2\pi r^2 + 2\pi rh$) 138.16 cm^2] with plastic lids having a mesh-covered hole for ventilation. Aphids were transferred to the Petri dishes with a fine soft brush. A single *A. fasciatopunctata revelierei*larva of the second, third and fourth developmental stages and a female were then individually added to the cells. Since the first larval instars of the predator needed to live together and feed on their own eggshells after hatching, all first instar larvae were kept in the same Petri dishes for each prey density group, then aphids were added to the Petri dishes daily until they molted to the second instar. The number of aphids provided for each group was calculated by multiplying the number of larvae in each group by the number of aphids given to an individual. The daily consumption rate of the first instar was calculated by dividing the number of aphids consumed by the number of first instar larvae in the Petri dishes. The number of prey consumed by each larval stage and adult female predator at each density was recorded 24 h after the start of the experiment. Similarly, the development time, longevity and reproductive numerical response of *A. fasciatopunctata revelierei* to different prey densities were studied.

Data analysis

Experiments were carried out with at least ten replicates. One-way ANOVA was used to analyze the effects of different prey densities on the developmental time, longevity and fecundity of the predator. When significant differences were detected, means were compared by Duncan's multiple range test (DMRT) at $P < 0.05$.

The behavioral response of *A. fasciatopunctata revelierei* to the various prey densities was expressed by fitting Holling's equation to the data (Holling 1959):

$$N_a = aTN/(1 + aT_hN),$$

where N_a is the number of prey attacked by a predator, T is the exposure time (1 day), P is the predator (= 1), N is the prey density per unit area, a is the search rate of the predator and T_h the handling time of each prey caught. The search rate and handling time were calculated from nonlinear regression of the disc equation. All data were analyzed by SAS statistical software (SAS Institute 1998).

Results

The consumption rate of each larval stage and adult female tested in this study increased as the prey density increased, then leveled off. The consumption rate of the second instar larvae increased up to a density of 40 prey, while those of the third and fourth stages increased up to 80 aphids/day. The predation rate of the third instar larvae was higher than that of the second instar larvae at all prey densities; and the predation rate of the fourth instar larvae was higher than that of third instar larvae at prey densities of 160 aphids/day and higher. Adult female predators consumed more aphids than all the larval stages and their prey consumption increased with increasing prey density, up to 160 prey/day and then leveled off (Fig. 1). Although the search rate of each instar larva was always close, the handling time was notably shorter for the fourth instar ($T_h = 0.0114$) because of the more rapid aphid consumption at densities of 160 prey and above (Table 1). The search rate and handling time of adult females were lower than those of all larval stages ($a = 1.4795$, $T_h = 0.029$; Table 1).

Developmental time was affected by prey densities. While increasing prey densities did not shorten the time taken by each immature developmental stage individually, the total developmental time (from first instar larva

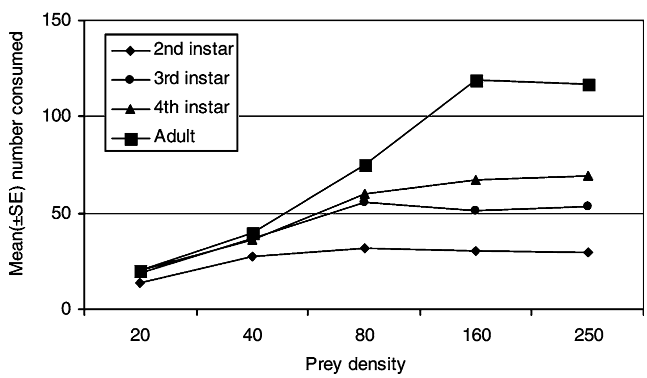

Fig. 1 Mean consumption of *A. fasciatopunctata revelierei* immature stages and adult females feeding on different densities of *H. pruni*

Table 1 Search rate (*a*), handling time (T_h) and confidence limits in Holling's disc equation for *A. fasciatopunctata revelierei* feeding on different prey densities of *H. pruni*

Stage	*a* (nymph/day)	95% confidence limit		T_h(day/nymph)	95% confidence limit	
		Lower	Upper		Lower	Upper
2nd instar	1.8784	−0.8818	4.6386	0.029	0.0179	0.0402
3rd instar	2.0605	−0.4467	4.5677	0.0157	0.0090	0.0240
4th instar	1.6733	0.6233	2.7233	0.0114	0.0081	0.0147
Adult	1.4795	0.3478	0.3725	0.00524	0.0019	0.0850

Table 2 Mean duration of development of the immature stages of *A. fasciatopunctata revelierei* feeding on different prey densities of *H. pruni* (mean ± SE). In each column, means followed by same letter are not statistically different (DMRT, $P < 0.05$)

Prey density	*n*	Duration of developmental stage (day)						Total
		1st instar	2nd instar	3rd instar	4th instar	Prepupa	Pupa	
20	10	2.40 ± 0.24a	3.00 ± 0.32a	3.25 ± 0.25a	4.71 ± 0.52a	1.0 ± 0.00a	4.60 ± 0.24a	18.80 ± 0.58a
40	10	2.00 ± 0.00a	2.83 ± 0.17a	3.50 ± 0.22a	4.63 ± 0.18a	1.0 ± 0.00a	3.83 ± 0.31a	17.83 ± 0.40ab
80	10	2.25 ± 0.25a	3.17 ± 0.10a	2.75 ± 0.25a	3.80 ± 0.18a	1.0 ± 0.00a	4.00 ± 0.37a	16.83 ± 0.65b
160	10	2.25 ± 0.25a	2.75 ± 0.25a	3.00 ± 0.58a	4.17 ± 0.17a	1.0 ± 0.00a	4.25 ± 0.25a	16.25 ± 0.25b
250	10	2.12 ± 0.54a	2.81 ± 0.38a	3.43 ± 0.62a	4.33 ± 0.19a	1.0 ± 0.00a	4.16 ± 0.46a	16.36 ± 0.32b

to adult) shortened with increasing prey density, up to 40 prey/day. The shortest developmental time was obtained at a prey density of 160 aphids/day (16.25 days) and the longest was obtained at a prey density of 20 aphids/day (18.80 days; Table 2).

The duration of the preoviposition and oviposition periods did not vary with increasing prey density, up to 160 prey/day. When 160 prey/day was provided, both the duration of both the preoviposition and oviposition periods shortened. There were significant differences between the duration of preoviposition for females fed with 20, 40, 80 prey/day and females fed with 160 prey/day and 250 prey/day (Table 3). The duration of oviposition for females fed with 160 prey/day was about two-fold that of females fed with prey densities lower than 160 prey/day (26.00, 27.00, 28.33, 43.33, 38.21 days at densities of 20, 40, 80, 160, 250 prey/day, respectively). The duration of the postoviposition period of the predator shortened with ≥80 prey/day. Feeding with different prey densities had a pronounced effect on the longevity of the adult female. The period shortened with ≥160 prey/day (Table 3).

The daily rate of oviposition and the overall fecundity increased as the prey increased, up to 160 prey/day (Table 3). The daily and overall fecundity of the predator at densities of 160 prey/day and 250 prey/day were significantly higher than at densities lower than 160 prey/day.

Discussion

The daily mean prey consumptions of *A. fasciatopunctata revelierei* larvae and adult females increased with increasing prey density. The prey consumption of *A. fasciatopunctata revelierei* larvae increased with increasing prey density, up to 40 aphids/day for second instars, up to 80 aphids/day for third and fourth instar larvae and up to 160 aphids/day for adult females. Since the search rate of females was higher than that of the larval instars and the search rate of the fourth instar larvae was higher than that of younger instars, any estimate of the predation capacity of a population of *A. fasciatopunctata revelierei* should include a consideration of the life stages

Table 3 Longevity and fecundity of *A. fasciatopunctata revelierei* females fed with different prey densities of *H. pruni* (mean ± SE). In each column, means followed by the same letter are not statistically different (DMRT, $P < 0.01$)

Prey density	Duration of different periods (days)			Longevity (days)	Fecundity (number of eggs/female)	
	Preoviposition	Oviposition	Postoviposition		Daily	Overall
20	7.00 ± 0.58a	26.00 ± 2.00a	3.0 ± 1.00a	35.67 ± 4.41a	3.43 ± 0.45a	89.00 ± 11.29a
40	5 75 ± 0.48a	27.00 ± 2.00a	5.0 ± 1.00a	35.33 ± 2.03a	4.47 ± 0.66a	103.67 ± 18.98a
80	5.50 ± 0.65a	28.33 ± 1.33a	13.0 ± 5.20b	49.00 ± 3.00a	5.43 ± 0.33a	137.33 ± 50.54a
160	2.25 ± 0.63b	43.33 ± 1.86b	19.5 ± 0.50c	58.33 ± 5.49b	7.57 ± 0.78b	301.67 ± 60.60b
250	2.73 ± 0.56b	38.21 ± 1.24b	18.5 ± 0.50c	57.16 ± 4.08b	7.28 ± 0.93b	298.15 ± 26.18b

and larval instars. It was reported that the consumption rate of adult females of some other coccinellids was higher than that of their larval instars (Uygun and Atlıhan 2000; Wang and Tsai 2001; Yaşar et al. 2000; Kaydan and Yaşar 1999). Functional response data for all larval stages and adult females of *A. fasciatopunctata revelierei* closely fit to Holling's type II response, because the curve of the disc equation reached a plateau within the density range tested (Fig. 1). Several other studies on the functional reponse of coccinellids are in agreement with the results described here (Hazard and Ferro 1991; Uygun and Atlıhan 2000; Atlıhan and Özgökçe 2002).

Although the larval developmental time (from first instar to adult) of the predator at a density of 20 prey/day was longer than that at densities >20 prey/day, larvae were able to develop to adulthood and complete the life cycle at all prey densities used in this study. Atlıhan et al. (2004) reported that a shorter developmental time with higher prey densities was due to the fact that energy needed by the larvae to develop into adults was acquired within a shorter time at higher prey densities. Results reported for some other coccinellids and a generalist predator (*Chrysoperla carnea*) showed similarity with the results obtained in this study (Kawauchi 1987; Atlıhan 1997; Atlıhan et al. 2004).

Feeding with a different prey density had an effect on the longevity and reproduction of the predator. Longevity was shorter at prey densities lower than 160 prey/day and both the daily and total fecundity were lower at prey densities lower than 160 prey/day. According to these results, it might be assumed that the predator can show its true potential for longevity and reproduction at a prey density higher than 80 prey/day.

According to the results obtained in this study, this predator has the potential for biological control of *H. pruni*, because it completes its development to adult and continues its reproduction even at low prey density and because it has a considerably high feeding capacity. Results obtained in the laboratory can give important insights, but to draw firm conclusions, the potential of this predator for biological control should be investigated in field conditions.

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References

Atlıhan R, Kaydan B, Özgokçe MS (2004) Feeding activity and life history characteristics of the generalist predator, *Chrysoperla carnea* (Neuroptera: Chrysopidae) at different prey densities. J Pest Sci 77:17–21

Atlıhan R (1997) Investigations into the biology and ecology of *Symnus levaillanti* (Mulsant) (Coleoptera: Coccinellidae) (in Turkish, summary in English). PhD thesis, University of Çukurova, Adana

Atlıhan R, Özgökçe MS (2002) Development, fecundity and prey consumption of *Exochomus nigromaculatus* feeding on *Hyalopterus pruni*. Phytoparasitica 30:443–450

Atlıhan R, Denizhan E, Yaşar B (1999) Effects of different preys on development and fecundity of *Scymnus subvillosus* Goeze (Coleoptera: Coccinellidae) (in Turkish, summary in English). Proc Turk Nat Congr Biol Control 4:397–406

Basky ZS (1982) Predators and parasites of *Hyalopterus pruni* and *Hyalopterus amygdali* populations living on peach, plum and reed. Acta Phytopathol Acad Sci Hung 17:311–316

Blackman RL, Eastop VF (1984) Aphids on the world's crops: an identification and information guide. Wiley, Chichester

Dixon AFG (1987) The way of life of aphids: host specificity, speciation and distribution. In: Minsk AK, Harrewijn P (eds) Aphids, their biology, natural enemies and control. (Systematics, vol A) Elsevier, Tokyo, pp 197–207

Erol T, Yaşar B (1996) Studies on determination of harmful and beneficial fauna in the apple orchards in Van province (in Turkish, summary in English). Turk J Entomol 20:281–293

Fan Y, Petitt FL (1994) Parameter estimation of the functional response. Environ Entomol 23:785–794

Frazer BD (1988) Predators. In: Minsk AK, Harrewijn P (eds) Aphids, their biology, natural enemies and control. (Systematics, vol A) Elsevier, Tokyo, pp 217–230

Gitonga LM, Overholt WA, Löhr B, Magambo JK, Mueke JM (2002) Functional response of *Orius albidipennis* (Hemiptera: Anthocoridae) to *Megalurothrips sjostedti* (Thysanoptera: Thripidae). Biol Control 24:1–6

Hazard RV, Ferro DN (1991) Feeding responses of adult *Coleomegilla maculata*(Coleoptera: Coccinellidae) to eggs of Colorado potato beetle (Coleoptera: Chrysomelidae) and green peach aphids (Homoptera: Aphididae). Environ Entomol 20:644–651

Heimpel GE, Hough-Goldstein JA (1994) Components of the functional response of *Perillus bioculatus* (Hemiptera: Pentatomidae). Environ Entomol 23:855–859

Hodek I (1973) Biology of Coccinellidae. Junk, the Hague

Holling CS (1959) The components of predation as revealed by a study of small mammal-predation European pine sawfly. Can Entomol 91:293–320

Iperti G (1999) Biodiversity of predaceus Coccinellidae in relation to bioindication and economic importance. Agric Ecosyst Environ 74:323–342

Kasap I, Yaşar B (1996) Studies on the life table of *Exochomus nigromaculatus* Goeze (Col.: Coccinellidae) feeding on *Hyalopterus pruni* (Geoffr.) (Hom.: Aphididae) and *Chaitophorus leucomelas*Koch (Hom.: Chaitophoridae) (in Turkish, summary in English). Proc Turk Nat Congr Entomol 3:675–681

Kawauchi S (1987) Effects of prey density on the consumption, development and survival of *Scymnus hoffmanni* (Coleoptera: Coccinellidae). Kurume Univ J 36:151–155

Kaydan MB, Yaşar B (1999) The determining of the numerical and functional responses and the duration of resistance to hungry of *Scymnus apetzi* (Mulsant) (Coleoptera: Coccinellidae) feeding on *Hyalopterus pruni* (Geoffroy) (Hom.: Aphididae) (in Turkish, summary in English). J Agric Sci 9:29–35

Kumar N, Kumar A, Tripathi CPM (2002) Satiation time and appetive revival of *Coccinella septempunctata* L. (Col., Coccinellidae) a predator of *Lipaphis erysimi* Kalt. (Hom.: Aphididae). J Appl Entomol 126:46–49

Munyaneza J, Obrycki JJ (1997) Functional response of *Coleomegilla maculata* (Coleoptera: Coccinellidae) to Colorado potato beetle eggs (Coleoptera: Chrysomelidae). Biol Control 8:215–224

Öncüer C (1991) A catalogue of the parasites and predators of insect pests of Turkey (in Turkish, summary in English). Ege University Agriculture Faculty, Izmir

Özgen I, Yaşar B (1999) Effect on different mating numbers on life table parameters of *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) feeding on *Hyalopterus pruni* (Geoffroy) (Homoptera: Aphididae) (in Turkish, summary in English). Proc Turk Nat Congr Biol Control 4:385–396

Rogers D (1972) Random search and insect population models. J Anim Ecol 41:369–383

SAS Institute (1998) Statistical nalysis software, user's manual, ver 8.01. SAS Institute, USA

Toros S, Yaşar B, Özgökçe MS, Kasap I (1996) Studies on determination of Aphidoidea species in Van province (in Turkish, summary in English). Proc Turk Nat Entomol Congr 3:549–556

Uygun N, Atlıhan R (2000) The effect of temparature on development and fecundity of *Scymnus levailanthi*. BioControl 45:453–462

Wang JJ, Tsai JH (2001) Development and functional response of *Coleophora inaequalis*(Coleoptera: Coccinellidae) feeding on brown citrus aphid, *Toxoptera citricida* (Homoptera: Aphididae). Agric For Entomol 3:65–69

Wiedenmann RN, O'Neil RJ (1991) Laboratory measurement of the functional response of *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae). Environ Entomol 20:610–614

Williams FM, Juliano SA (1996) Functional responses revised. Environ Entomol 25:549–550

Yaşar B, Özgökçe MS (1994) The life tables of *Hippodamia variegata*(Goeze) and *Synharmonia conglobata*(L.) (Col.: Coccinellidae) feeding on *Hyalopterus pruni*(Geoffroy) (Hom.: Aphididae) and their resisting period to hungry in laboratory conditions (in Turkish, summary in English). J Agric Fac 4:31–44

Yaşar B, Özgökçe MS, Kasap I (1999) Investigations on the predator species belong to Coccinellidae (Coleoptera) family occurred in Van province (in Turkish, summary in English). Proc Turk Nat Congr Biol Control 4:445–454

Yaşar B, Denizhan E, Aydı n G (2000) The determining of the numerical and development responses and resistance to starvation of *Semiadalia undecimnotata* (Schneider) (Coleoptera: Coccinellidae) feeding on *Hyalopterus pruni* (Geoffr.) (Homoptera: Aphididae) (in Turkish, summary in English). Proc Turk Nat Entomol Congr 4:329–338