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Effect of three diaspididae prey species on development and fecundity of the ladybeetle *Chilocorus bipustulatus* in the laboratory

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Abstract. The purpose of this investigation was to determine the most suitable prey for the development and fecundity of the predatory coccinellid, *Chilocorus bipustulatus* (L.) on three different diaspidid species: *Aspidiotus nerii* Bouché, *Aonidiella aurantii* (Maskell), and *Pseudaulacaspis pentagona* (Targioni-Tozzetti). Life tables were constructed at constant 25 °C and the developmental time, longevity, fecundity, and the sex ratio were determined. Individuals fed with *A. nerii* displayed the shortest larval and pupal developmental time (26.0 days), lowest immature mortality rate (16.6%), highest net reproduction rate (264.7 females/female), shortest generation time (72.9 days), and the highest intrinsic rate of increase (0.077 females/female/day). The results showed that under laboratory conditions *C. bipustulatus* developed best on *A. nerii*.

Key words: *Aonidiella aurantii*, *Aspidiotus nerii*, Coccinellidae, Coleoptera, development, fecundity, predator, *Pseudaulacaspis pentagona*

Introduction

Citrus production in Turkey is mainly concentrated in the east Mediterranean region, where about 70% of all trees are located. A serious pest of citrus in this region is *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae) causing high losses in yield and fruit quality each year (Uygun et al., 1987; Karaca and Uygun, 1990; Uygun et al., 1992). Because insecticides did not show long lasting effect in controlling *A. aurantii* and often destroy the natural balance, biological control was considered to be the only reliable technique in managing this pest (Ben-Dov and Rosen, 1969). For the biological control of *A. aurantii*, *Aphytis* spp. (Hymenoptera: Aphelinidae) and *Chilocorus* spp. (Coleoptera: Coccinellidae) were found to be the most effective natural enemies (Debach, 1960; Bedford, 1968; Ben-Dov and Rosen, 1969; Soylu, 1978). In South Africa, the effect of *Aphytis* spp. and *C. nigritus* (F.) have been found to be complementary in controlling *A. aurantii* on citrus

(Samways, 1988). In a mass release study in South Africa, *C. distigma* Klug. controlled *A. aurantii* population effectively three years after release (Bedford, 1968). *Chilocorus* spp. is generally a predator of diaspidids, coccids and pseudococcids (Avidov and Yinon, 1969; Yinon, 1969). In the east Mediterranean region of Turkey *C. bipustulatus* (L.) is the most abundant *Chilocorus* species (Uygun, 1981). Kansu and Uygun (1980) stated that *A. aurantii* was the main pest of citrus in this region and *C. bipustulatus* was one of the most effective predators. Karaca and Uygun (1990), determined *A. melinus* DeBach and *C. bipustulatus* as the most common natural enemies of *A. aurantii*. Uygun et al. (1992) stated that besides *A. melinus*, the predators *C. bipustulatus* and *Lindorus lophantae* Motsch played a decisive role in retarding the build-up of the pest population.

Thus, *C. bipustulatus* has to be considered as an important natural enemy of *A. aurantii* in the east Mediterranean region of Turkey. This study was aimed at determining how each of the three species, *Aspidiotus nerii* Bouché, *A. aurantii* and *Pseudaulacaspis pentagona* (Targioni-Tozzetti) affected developmental time, longevity, fecundity, mortality rate, and sex ratio of *C. bipustulatus*. This information will faciliate rearing and further studies on the biology of *C. bipustulatus* in pursuit of enhancing its biocontrol potential.

Materials and methods

Development and mortality rate of immature stages

A. nerii and *P. pentagona* were cultured on potatoes, but since *A. aurantii* could not be reared on potatoes, squash served as the rearing substrate for this prey. Adults of the predator were obtained from the citrus orchards near Adana in the east Mediterranean region and were reared on *A. nerii* in a climatic room at the Department of Plant Protection, University of Çukurova, Adana, Turkey. *C. bipustulatus* were reared in the laboratory on *A. nerii* for about one year before individuals were used in the experiments.

Developmental time and mortality of immature stages on different prey species were studied by transferring a single newly hatched predator larva into a cage with either *A. nerii* or *P. pentagona* on potatoes as food. In the experiments with *A. aurantii*, the predator larvae were confined to squash by a plastic cell (diam. 5 cm). By daily observations the duration and the mortality of different developmental stages were recorded. To determine the mortality during the egg stage, eggs laid by *C. bipustulatus* fed with different scale insects during development were observed daily until hatching.

Longevity and fecundity

Because it is not possible to determine the sex of live *C. bipustulatus*, fecundity was determined by confining 3–5 one-day-old adults into the same cage or cell with unlimited food. Ten replicates were set up for *A. aurantii*, *P. pentagona* (in total 36 adults for each prey), whilst 45 adults were tested for *A. nerii* (12 replicates). The duration of preoviposition, oviposition and postoviposition periods, longevity and the number of eggs laid per cage and cell were recorded by daily observations until all adults died. Dead individuals were collected and the sex determined after preparation of genitalia according to Uygun (1981). The number of eggs laid per female was calculated by dividing the number of eggs per cage or cell by the number of females. To determine the effect of different prey species on the sex ratio of *C. bipustulatus*, larvae were fed with the three different prey species separately and the sex of subsequent emerged adults was determined.

All experiments were conducted in a climatic chamber at 25 ± 1 °C, 60 ± 5% relative humidity and a photoperiod of 16 hours light. Differences in the developmental time and fecundity were examined by analysis of variance and Fisher’s Least Significant Difference test. The data obtained from daily observations were used to construct life tables according to Southwood (1978).

Results

Development and mortality of immature stages

The total developmental time of *C. bipustulatus* displayed statistically significant differences among all three prey species provided (Table 1). The time from the first larval stage to adult was low for *A. nerii* with 26.0 days and high for *P. pentagona* with 33.9 days.

The mortality rate of eggs ranged from 9.6% on *A. nerii* to 43.2% on *P. pentagona*. No mortality occurred for the fourth larval and the pupal stages (Table 2). The total mortality of all immature stages was low for *A. nerii* (16.6%) and *A. aurantii* (19.4%) but considerably higher when *P. pentagona* was provided as prey (46.9%).

Longevity and fecundity

The preoviposition period of *C. bipustulatus* was shortest on *A. nerii* with an average of 9.6 days. The oviposition period was significantly longer on *A. nerii* (126.5 days) and *A. aurantii* (117.4 days) than on *P. pentagona* (79.4

Table 1. Mean duration of immature stages of *Chilocorus bipustulatus* feeding on different prey species

		Duration of immature stages (days)					Total(days)
Prey	n	Stage 1 mean+SE (min.–max.)	Stage 2 mean+SE (min.–max.)	Stage 3 mean+SE (min.–max.)	Stage 4 mean+SE (min.–max.)	PUPA mean+SE (min.–max.)	(Stage 1–Adult) mean+SE (min.–max.)
Aspidiotus nerii	50	3.5+0.17 a (2–7)	3.3+0.15 a (2–7)	4.4+0.12 a (2–7)	6.0+0.17 a (3–8)	8.8+0.14 b (6–11)	26.0+0.41 a (21–33)
Aonidiella aurantii	50	4.5+0.17 b (3–7)	4.3+0.10 b (3–6)	5.1+0.11 b (4–7)	6.4+0.17 a (4–8)	7.5+0.22 a (4–10)	27.8+0.40 b (22–35)
Pseudaulacaspis pentagona	44	5.8+0.16 c (4–8)	5.0+0.26 c (2–10)	5.1+0.22 b (3–10)	9.0+0.42 b (6–18)	9.0+0.17 b (7–12)	33.9+0.61 c (27–45)

Means in columns followed by the same letter are not significantly different according to LSD test ($p = 0.05$).

Table 2. Mortality rate of egg and immature stages of *Chilocorus bipustulatus* feeding on different prey species

	Mortality during egg stage		Mortality of immature stages (%)						Total mortality of all immature stages	
Prey	n	%	n	L1	L2	L3	L4	Pupa	n	%
Aspidiotus nerii	321	9.6	60	11.6	3.7	1.9	0.0	0.0	60	16.6
Aonidiella aurantii	309	13.2	62	12.9	5.6	2.0	0.0	0.0	62	19.4
Pseudaulacaspis pentagona	273	43.2	83	26.5	18.0	12.0	0.0	0.0	83	46.9

days). Longevity of females was greater on *A. nerii* and *A. aurantii* (146.5 and 132.6 days, respectively) than on *P. pentagona* (95.9 days). Adult males survived longer on *A. nerii* (135.3 days) than on *P. pentagona* (79.0 days, Table 3).

Fecundity differed statistically for all three prey species. The mean number of eggs produced by a single female was on average 528.6, 294.2 and 179.7 on *A. nerii*, *A. aurantii* and *P. pentagona*, respectively (Table 4).

According to the life tables, there was a high survival rate for *C. bipustulatus* when feeding on *A. nerii* and *A. aurantii* compared to *P. pentagona* (Figure 1). Adults fed on *A. nerii* had a longer oviposition period and continued to lay eggs with only a slow decrease throughout the entire life span. On the other hand, females fed on *A. aurantii* and *P. pentagona* deposited most of their eggs by the middle of their oviposition period and the rates declined gradually, showing a similar trend to that of the survivorship curves. The net reproduction rate (R_o) was highest on *A. nerii* with 264.7 females/female and lowest on *P. pentagona* with 31.1 females/female (Figure 1). The intrinsic rate of increase (r_m) showed significant differences on different preys being highest on *A. nerii* (0.077 females/female/day). This was mainly due to high reproduction rate and a shorter generation time in this treatment.

Table 3. Mean duration of preoviposition, oviposition, postoviposition periods and longevity of *Chilocorus bipustulatus* feeding on different prey species

	Duration of different periods (days)				Longevity (days)			
		Preoviposition	Oviposition	Postoviposition		Female		Male
Prey	n	mean+SE (min.–max.)	mean+SE (min.–max.)	mean+SE (min.–max.)	n	mean+SE (min.–max.)	n	mean+SE (min.–max.)
Aspidiotus nerii	29	9.6+0.26 a (8–12)	126.5+9.00 b (44–198)	9.9+0.86 a (6–15)	29	146.5+9.14 (59–220)	16	135.3+7.06 (80–171)
Aonidiella aurantii	21	12.8+0.43 b (10–14)	117.4+5.00 b (87–148)	6.2+1.56 a (0–13)	21	132.6+4.83 (86–169)	15	114.3+6.90 (61–162)
Pseudaulacaspis pentagona	13	12.2+0.43 b (10–14)	79.4+4.5 a (54–109)	6.8+1.76 a (0–14)	13	95.9+4.46 (71–125)	23	79.0+5.38 (33–127)

Means in columns followed by the same letter are not significantly different according to LSD test ($p = 0.05$).

Table 4. Sex ratio and fecundity of *Chilocorus bipustulatus* feeding on different prey species

	Sex Ratio (%)			Fecundity			Duration of egg stage	
Prey	n	Female	Male	n	No. of eggs/ female/ day mean+SE (min.–max.)	Total No. of eggs laid/ female mean+SE (min.–max.)	n	(days) mean+SE (min.–max.)
Aspidiotus nerii	244	66.8	33.2	29	4.2+0.38 b (0–13)	528.6+32.7 c (331–686)	50	7.6+0.09 a (7–9)
Aonidiella aurantii	236	64.8	35.2	21	2.5+0.47 a (0–8)	294.2+18.1 b (171–355)	50	8.7+0.09 b (7–11)
Pseudaulacaspis pentagona	236	33.4	66.6	13	2.3+0.44 a (0–11)	179.7+10.2 a (147–242)	44	10.8+0.22 c (9–1)

Means in columns followed by the same letter are not significantly different according to LSD ($p = 0.05$) test.

Conclusion

There is little information available in the literature about the effect of the three tested scale insects on development and fecundity of *C. bipustulatus*. Bodenheimer (1951) stated that *C. bipustulatus* mostly fed on diaspidids and among them preferred *A. nerii*. The same author reported the duration of the egg, larval and pupal stages as 7–28, 15–81 and 4–31 days, respectively. Nadel and Biron (1964) observed in their experiments at 25 °C that the duration of larval and pupal stages of *C. bipustulatus* varied from 30 to 43 days on *Chrysomphalus aonidum* (L.) (Homoptera: Diaspididae), which matches well with the results that we observed for *P. pentagona*. Öncüer (1983) reported that in his experiments at 25 °C the duration of larval and pupal stages varied from 30 to 33 days on *Quadrispidiotus perniciosus* (Comstock) (Homoptera: Diaspididae) which was similar to our the results for *A. aurantii*. Hattingh and Samways (1994a) reported a larval and pupal development period of 29 days at 25–26 °C when fed on *A. nerii*, which is slightly longer than was found in this study. Kasap and Yaşar (1995) observed a mean developmental time of larval and pupal stages of 25.74 days at 25 °C when *C. bipustulatus* were offered eggs of *Chionaspis salicis* (L.) (Homoptera: Diaspididae).

Kasap and Yaşar (1995) reported that the preoviposition, oviposition and postoviposition periods lasted 14.42, 87.14 and 7.85 days, respectively. Although we did not use either *Q. perniciosus* or *C. salicis*, our results from *A. aurantii* are similar to those mentioned in Öncüer (1983) and Kasap and

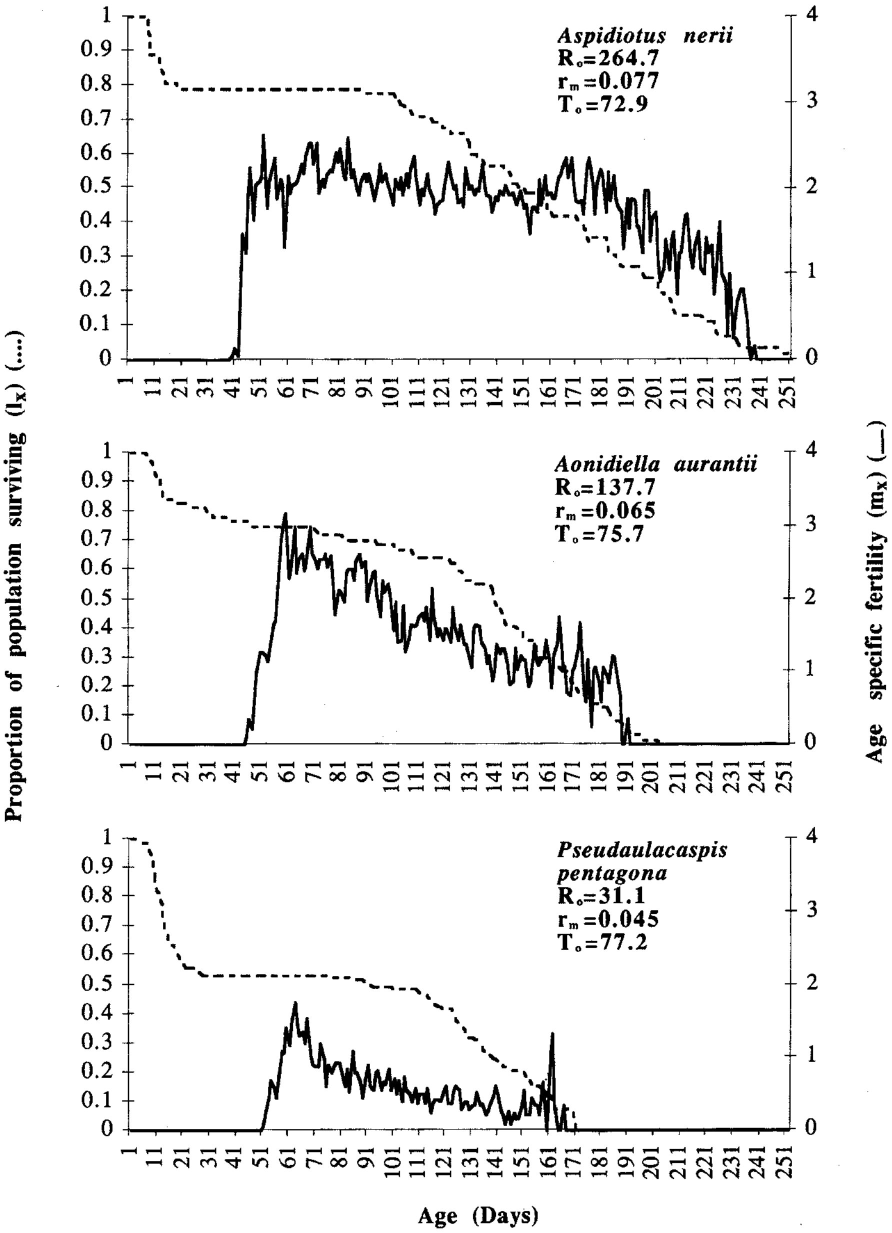

Figure 1. Survivorship curve (l_x) and age specific fecundity rate (m_x) of *Chilocorus bipustulatus* feeding on different prey species.

Yaşar (1995). We can consider that three of those diaspidid species may have similar effects on developmental time of immature stages of *C. bipustulatus*. Hattingh and Samways (1994a) recorded 3.8 eggs per female per day when fed on *A. nerii*, which is very close to the rate observed in our data. Bodenheimer (1951) reported the longevity of adults on *A. nerii* as 30–250 days, whereas in our experiments the adults feeding on the same prey lived 59–220 days. Öncüer (1983) reported a longevity of 143 days for *C. bipustulatus* on *Q. perniciosus*, which matches our results with *A. nerii*. Hattingh and Samways (1994b), stated that *A. nerii* was superior to *Asterolecanium miliaris* (Homoptera: Diaspididae) as prey for *C. bipustulatus* larvae and attributed the failure to establish *C. bipustulatus* in South Africa as being due to prey suitability. Yinon (1969), stated that *C. bipustulatus* preferred *A. nerii* and *A. aurantii* over *P. pentagona*.

There is little information in the literature on prey-mediated change in sex ratio of *C. bipustulatus.* Öncüer (1983) stated that when *C. bipustulatus* was fed with *Q. perniciosus* and eggs of *Ceroplastes rusci* Comstock (Homoptera: Coccidae) the female/male ratio was 1/1 and 1/2, respectively. Kasap and Yaşar (1995), found a female/male ratio of 1/1 when *C. bipustulatus* was provided with eggs of *C. salicis*. The results of this study indicate that sex ratio is influenced extensively by prey type ranging from 1/2 to 2/1.

The results showed that *C. bipustulatus* fed with *A. nerii* displayed the shortest developmental time, lowest mortality rate, highest net reproduction rate, shortest generation time and highest intrinsic rate of increase compared to the other diaspidid species tested. *C. bipustulatus* was maintained on *A. nerii* in the mass culture for more than one year, and although this prey experience may explain some of the differences observed, it is not believed to be responsible for the overall suitability of *A. nerii* as food.

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