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Development and immature survival of two aphidophagous ladybirds, *Coelophora biplagiata* and *Micraspis discolor*

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Abstract The developmental parameters, namely developmental periods, larval survival, adult emergence, growth index, developmental rate and sex ratio in terms of female proportion in a population of two aphidophagous ladybirds, namely, *Coelophora biplagiata* (Swartz) and *Micraspis discolor* (Fabricius) were investigated, using three aphid species as prey. The immature stages of *C. biplagiata* were significantly affected by prey quality and developed fastest when fed on *Aphis craccivora* followed by *Aphis gossypii* and *Rhopalosiphum maidis*. The order of prey suitability in terms of developmental rate of immature stages of *M. discolor* was just reversed. The adult females were heavier than males, while pre-pupae were heavier than pupae in both ladybirds. The sex ratio of adult emergence, though female-biased in both ladybird species, was not significantly affected by prey quality.

Key words aphids, Coccinellidae, *Coelophora biplagiata*, development, immature survival, *Micraspis discolor*
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Introduction

Prey quality has a major influence on growth, development and immature survival of predaceous insects, especially ladybirds (Coleoptera: Coccinellidae), which are biocontrol agents of several phytophagous insect pests, like aphids, diaspids, coccids, adelgids, aleyrodids and so on (Hodek & Honek, 1996; Dixon, 2000). The impact of prey quality on various life attributes of ladybirds can also estimate the prey suitability (Kalushkov & Hodek, 2001). Numerous research on prey quality effects have been made on bio-attributes of commonly occurring ladybirds (Omkar & Srivastava, 2003; Omkar & Bind, 2004; Omkar & James, 2004; Pervez & Omkar, 2004; Omkar & Mishra, 2005; Omkar *et al*., 2005a, b) with a perspective to utilize them for mass-multiplication and aphid biocontrol; however little is known about less abundant ladybirds.

Coelophora biplagiata (Swartz) is a black colored polymorphic ladybird occurring in typical and melanic forms. Little is known about its prey record with sporadic incidences on colonies of *Aphis craccivora* Koch (Saharia, 1980), *A. gossypii* Glover (Kalita *et al*., 1998), and sugarcane wooly aphid, *Ceratovacuna lanigera* Zehnter in India (Joshi & Viraktamath, 2004) and in China (Deng *et al*., 1987). Besides, aphids, namely *Aphis pomi* de Geer, *Aphis saliceti* Kaltenbach and *Eulachnus piniformosanus* Takahashi were its alternative prey (Thompson & Simmonds, 1964). No information is available on its ecology and prey-predator interactions. The adults of *C. biplagiata* could be seen in the bean (*Dolichos lablab*) fields of Lucknow, India, preying on aphid, *A. craccivora*. They are bigger in size compared to their co-occurring ladybird species, namely *Cheilomenes sexmaculata* (Fabricius) and *Propylea dissecta* (Mulsant) (Pervez, per. obs.). On the basis of size it appears to be a promising biocontrol agent of *A. craccivora*. Hence, it would be interesting to know what would be the impact of *A. craccivora* along with other common aphid species on its development and other related parameters.

Micraspis discolor (Fabricius) is a red coloured ladybird occurring in local agricultural fields preying on aphids, *A. craccivora*, *A. gossypii*, and *Lipaphis erysimi* (Kalt.) (Omkar

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& Bind, 1993). The adults also feed on whiteflies (Herting & Simmonds, 1972), pollens of *Zea mays* (Omkar, unpubl. data), and artificial diets like synthetic diets and drone honey bee powder (Agarwala *et al*., 1988). However, aphids are better food in terms of development and reproduction (Agarwala & Senchowdhuri, 1989). A recent catalogue documents its prey record (Omkar & Pervez, 2004). It is a meagerly studied ladybird with little information on its life attributes (Agarwala *et al*., 1988). Thus, the present investigation was made to study the growth, development and immature survival of *C. biplagiata* and *M. discolor* using three aphid species, *A. craccivora*, *A. gossypii* and *Rhopalosiphum maidis* (Fitch) as prey.

Materials and methods

Stock maintenance

Adults of *C. biplagiata* and *M. discolor* were collected from local agricultural fields preying on aphids, *A. craccivora*, *A. gossypii* and *R. maidis* infested on *Dolichos lablab*, *Lagenaria vulgaris* and *Zea mays*, respectively. The adults of each species were brought to the laboratory, paired in Petri dishes (9.0 cm × 1.5 cm) and allowed to mate. The eggs obtained were separated and kept in Petri dishes.

Experimental design

Ten eggs of *C. biplagiata* and *M. discolor* each were kept in Petri dishes in an environmental test chamber under controlled conditions (27 ± 1℃, 65% ± 5% RH and 12: 12 L: D photoperiods). The first instars hatched were reared separately on *ad libitum* supply of aphid, *A. craccivora* infested on twigs of *D. lablab* till adult emergence. The observations on developmental period and survival were taken three times daily. The incubation period and durations of 1st, 2nd, 3rd and 4th instars, prepupae and pupae were recorded and each developing stage weighed using electronic balance AY 120 (at 0.1 mg precision). The emerging adults were sexed and isolated. The experiment was replicated 10 times (n = 10) and repeated using *A. gossypii* and *R. maidis* infesting pieces of leaves of *L. vulgaris* and *Z. mays*, respectively as prey. To maintain the purity of diet, the parents and larvae were provided with the same food.

The percent larval survival (number of pupae formed × 100/number of larvae hatched), percent adult emergence (number of adult emergence × 100/number of pupae), growth index (percent pupation/mean larval duration) and female proportion in the adult emergence (number of adult females/number of adults) was calculated. The developmental period, weight, developmental rate, percent larval survival, adult emergence and growth index of each ladybird species at varying prey diet was subjected to one-way ANOVA using statistical software MINITAB on a personal computer. Total developmental period of each ladybird species was subjected to Pearson's correlation analysis using MINITAB. The sex-ratios of adult emergence obtained at different prey species were subjected to chi-square Goodness-of-fit Test.

Results

The immature stages of *C. biplagiata* developed significantly fastest when fed on *A. craccivora* followed by *A. gossypii* and *R. maidis* (Table 1). The other developmental parameters, such as percent larval survival, percent adult emergence and growth index, were optimum on *A. craccivora* (Table 2). The order of prey suitability was reversed in *M. discolor* in terms of developmental rate, as immature stages developed fastest on *R. maidis* followed by *A. gossypii* and *A. craccivora* (Table 1).

The weight of immature stages increased significantly (P < 0.01; Table 1) with increase in subsequent stage. Larvae of *C. biplagiata* were heavier when fed on *A. craccivora* than those of *M. discolor* on *R. maidis* (Table 1). The prepupae of both *C. biplagiata* and *M. discolor* were heavier than pupae. The percent larval survival and growth index were significantly affected by prey quality, however adult emergence did not vary significantly (Table 2). The developmental period of *C. biplagiata* (r = −0.955; P < 0.001; df = 2) and *M. discolor* (r = −0.993; P < 0.001; df = 2) has a negative correlation with adult weight revealing that heavier immature stages developed faster than lighter ones. The sex ratios of adult emergence obtained at varying prey diets of each ladybird species were not significantly different (Table 2).

Discussion

The results revealed that prey quality significantly affected growth, development and immature survival of both the ladybirds, *C. biplagiata* and *M. discolor*. *Aphis craccivora* was the most suitable prey, supporting maximum development rate, larval survival, adult emergence and growth index in *C. biplagiata*. The immature stages weighed heaviest on *A. craccivora*. The finding supported the abundance of *C. biplagiata* in the vicinity of *A. craccivora* in field conditions. The order of suitability was *A. craccivora* followed by *A. gossypii* and *R. maidis*.

Table 1 Duration and weight of various life stages of *C. biplagiata* and *M. discolor* on three aphid species (n = 10).

Stage		*Coelophora biplagiata*				*Micraspis discolor*			
		A. craccivora	*A. gossypii*	*R. maidis*	*F*-value	*A. craccivora*	*A. gossypii*	*R. maidis*	*F*-value
Egg	D	2.08 ± 0.11	2.14 ± 0.12	2.15 ± 0.18	1.06	3.00 ± 0.07	3.20 ± 0.45	3.00 ± 0.00	2.20
	W	0.29 ± 0.00	0.29 ± 0.00	0.29 ± 0.00	–	0.16 ± 0.00	0.16 ± 0.00	0.16 ± 0.00	–
1st instar	D	1.98 ± 0.04	2.03 ± 0.06	2.10 ± 0.13	3.82*	1.36 ± 0.24	1.21 ± 0.21	1.04 ± 0.08	7.08*
	W	1.13 ± 0.51	1.03 ± 0.36	1.06 ± 0.29	0.16	1.53 ± 0.16	1.55 ± 0.21	1.55 ± 0.19	0.05
2nd instar	D	1.67 ± 0.27	1.88 ± 0.14	1.95 ± 0.20	4.60*	2.50 ± 0.53	2.20 ± 0.42	1.93 ± 0.40	3.92*
	W	4.36 ± 0.96	3.73 ± 0.44	3.58 ± 0.41	4.04*	2.37 ± 0.32	2.19 ± 0.21	2.11 ± 0.13	3.19*
3rd instar	D	1.89 ± 0.20	2.15 ± 0.18	2.17 ± 0.22	6.16*	2.30 ± 0.48	2.20 ± 0.42	2.00 ± 0.33	1.34
	W	9.26 ± 0.75	8.66 ± 0.90	7.66 ± 0.60	11.43*	3.72 ± 0.27	3.87 ± 0.26	4.05 ± 0.31	3.44*
4th instar	D	2.32 ± 0.19	2.56 ± 0.24	2.60 ± 0.24	4.35*	2.11 ± 0.11	2.04 ± 0.05	1.95 ± 0.09	8.77*
	W	18.77 ± 2.22	16.24 ± 1.60	15.79 ± 1.60	7.86*	8.58 ± 0.45	8.80 ± 0.50	9.20 ± 0.23	5.78*
Pre-pupa	D	0.66 ± 0.04	0.71 ± 0.08	0.76 ± 0.05	7.27*	1.20 ± 0.26	1.10 ± 0.17	1.12 ± 0.32	0.43
	W	30.22 ± 3.93	24.60 ± 2.64	23.15 ± 2.97	16.05*	7.09 ± 0.58	8.10 ± 0.58	8.83 ± 0.69	20.11*
Pupa	D	3.20 ± 0.09	3.36 ± 0.19	3.45 ± 0.11	8.73*	3.06 ± 0.08	2.40 ± 0.52	2.96 ± 0.08	13.51*
	W	26.82 ± 4.23	23.11 ± 2.97	21.09 ± 1.44	8.80*	6.61 ± 0.48	7.46 ± 0.57	7.95 ± 0.68	13.70*
Develop-ment	D	13.80 ± 0.51	14.83 ± 0.49	15.18 ± 0.43	22.30*	15.53 ± 0.87	14.35 ± 0.43	14.00 ± 0.67	13.68*
	W								
	Male	26.69 ± 3.54	23.88 ± 3.12	21.88 ± 2.24	6.40*	10.05 ± 1.45	10.54 ± 1.23	10.68 ± 1.22	0.68
	Female	34.09 ± 5.43	31.55 ± 2.14	28.79 ± 2.24	5.39*	13.49 ± 1.36	14.22 ± 1.36	14.59 ± 0.90	2.71

Values are mean ± SD; *significant at $P < 0.05$; D, days; W, weight in mg.

Table 2 Biological attributes of *C. biplagiata* and *M. discolor* on three aphid species (n = 10).

Ladybird	*Coelophora biplagiata*				*Micraspis discolor*			
Aphid species	*A. gossypii*	*A. craccivora*	*R. maidis*	Analysis	*A. gossypii*	*A. craccivora*	*R. maidis*	Analysis
Developmental rate (per day)	0.068 ± 0.00	0.073 ± 0.00	0.066 ± 0.00	$F = 23.25$*	0.070 ± 0.00	0.065 ± 0.01	0.072 ± 0.00	$F = 8.56$*
Larval survival (%)	74.53 ± 8.79	81.00 ± 7.38	73.67 ± 5.39	$F = 3.70$*	100.00 ± 0.00	95.00 ± 10.54	88.17 ± 4.60	$F = 8.00$
Adult emergence (%)	80.06 ± 6.73	96.53 ± 5.60	77.86 ± 12.40	$F = 13.55$*	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00	–
Growth index	8.12 ± 1.09	10.31 ± 0.94	7.60 ± 0.55	$F = 26.05$*	11.24 ± 1.43	10.72 ± 1.89	12.74 ± 0.66	$F = 5.70$
Female (sex ratio)	0.57	0.55	0.57	$\chi^2 = 0.11$	0.57	0.64	0.63	$\chi^2 = 0.12$

Values are mean ± SD; *significant at $P < 0.05$.

Conversely, immature stages of *M. discolor* developed fastest on *R. maidis* followed by *A. gossypii* and *A. craccivora*. The difference in prey suitability suggests that biochemical constituents of prey that may be nutritious to one predator might not be nutritious to another. Previous studies suggest that *A. craccivora* was one of the suitable prey for *Coccinella septempunctata* Linnaeus (Omkar & Srivastava, 2003), *C. sexmaculata* (Omkar & Bind, 2004) and *P. dissecta* (Pervez & Omkar, 2004). However, it was toxic to certain ladybird species, namely *Semiadalia undecimnotata* (Schneider) (Hodek, 1960) and *Harmonia axyridis* (Pallas) (Hukusima & Kamei, 1970). *Aphis craccivora* infested on host plant *Robinia pseudoacacia* Linnaeus sequesters toxicants like amines, canavanine and ethanolamine, which are deleterious to the ladybirds preying on them (Obatake & Suzuki, 1985).

The differential survival and developmental rates in *C. biplagiata* might be due to differences in prey consumption, utilization and assimilation. The possible decreased consumption of less suitable prey may lead to a state of semi-starvation, leading to slow development and decreased survival (Kawauchi, 1979). Prey quality significantly affected the percent larval survival and growth index except percent adult emergence in *M. discolor*. Regardless of prey quality, all the pupae of *M. discolor* developed into adults with no mortality, revealing them to be least vulnerable to mortality factors.

The pre-pupae were heavier than pupae, owing to biochemical changes during metamorphosis of pre-pupae into pupae. This may also be attributed to the slight water loss as a metabolic cost during this transformation (Isikber & Copland, 2001). The adult weight has a negative correlation with total developmental period suggesting that immature stages, which develop faster, should grow into heavier adults than those that develop slower. This is in close agreement with that of Pervez and Omkar (2004). Regardless of prey quality, the adult females of both ladybird species were significantly heavier than males. This might be due to the relative increased prey consumption, fat deposition and egg production (Omkar & James, 2004). Four hypotheses have been framed to explain size-dependent sexual dimorphism in ladybirds. First, it might be a consequence of selection for rapid development and early maturation of males, development constraint hypothesis (Fairbairn, 1990). Second, males begin developing their gonads earlier in their development than females and this has costs in terms of the growth rate that males can sustain, that is, the gonadal constraint hypothesis (Dixon, 2000). Third, females need to be relatively bigger in order to produce more eggs, the fecundity advantage hypothesis (Fairbairn, 1990). Last, smaller males will be favoured in mating systems dominated by scramble competition, owing to their lesser food requirements and giving more available time to mate searching, time and energy constraint hypothesis (Ghiselin, 1974; Reiss, 1989).

The sex ratio of adult emergence in each ladybird species, however female-biased, was not significantly affected by prey quality. Female-biased ratio in certain species of ladybirds has been ascribed to a diverse array of male-killing symbionts or bacteria (Majerus *et al*., 2000; Majerus & Majerus, 2000). A recent study revealed that prey quality has also a significant role in alteration of sex ratio, as more suitable food tends to alter the sex ratio towards more female biasness (Srivastava & Omkar, 2004).

Thus, it can be concluded that: (i) all three aphid species were suitable to immature stages of *C. biplagiata* and *M. discolor*; (ii) order of suitability was *Aphis craccivora* > *A. gossypii* > *R. maidis* for *C. biplagiata*, while reverse was the case for *M. discolor*; (iii) faster development of immature stages resulted in heavier adults; (iv) adult females were heavier than the males, while prepupae were heavier than the pupae in both ladybirds; and (v) sex ratio of adult emergence was female-biased and not significantly affected by prey quality.

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