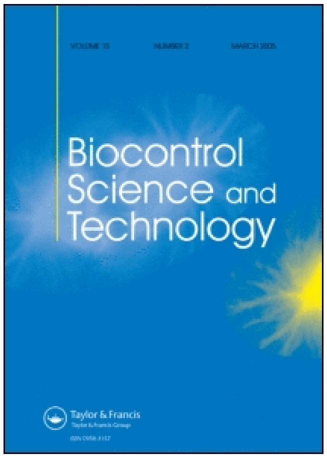

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Prey-Dependent Life Attributes of an Aphidophagous Ladybird Beetle, *Propylea dissecta* (Coleoptera: Coccinellidae)

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Predation potential, development, immature survival and reproduction of an aphidophagous ladybeetle, Propylea dissecta *(Mulsant) was studied when fed on seven aphid prey, viz.* Aphis gossypii, Aphis craccivora, Lipaphis erysimi, Uroleucon compositae, Brevicoryne brassicae, Rhopalosiphum maidis *and* Myzus persicae. A. gossypii *was most suitable and consumed by the larvae and adults of* P. dissecta*, while* M. persicae*, the least. Pre-imaginal development of* P. dissecta *was fastest (0.080 day^{-1}) when* A. gossypii *was used as prey, whilst slowest (0.061 day^{-1}) on* M. persicae. *The immature survival, adult emergence, adult male and female longevity of* P. dissecta *was maximal (i.e., 77.10 ± 0.04 and 93.21 ± 0.79%, 57.10 ± 1.62 and 62.40 ± 1.93 days, respectively) on* A. gossypii *and minimal (i.e., 63.01 ± 1.87 and 81.73 ± 1.79%, 42.50 ± 1.21 and 49.40 ± 2.32 days, respectively) when* M. persicae *was provided as prey. Oviposition period, fecundity, percent egg viability and mean reproductive rate was maximum (i.e., 50.30 ± 2.03 days, 856.00 ± 30.00 eggs, 96.40 ± 0.31% and 17.02 eggs per day) on* A. gossypii*, and minimum (i.e., 18.00 ± 1.40 days, 212.00 ± 18.21 eggs, 72.46 ± 2.81% and 11.78 eggs per day) on* M. persicae. *Adult weight and developmental rate of* P. dissecta *have a positive correlation, which suggests that if immature stages of ladybeetle developed faster, they should grow into heavier adults. Female longevity and fecundity also have a positive correlation. The findings also reveal that all seven aphid species tested are essential food. Rank order of prey species was consistent in all experimental parameters.*

Keywords: Propylea dissecta*,* Aphis gossypii*, Coccinellidae, aphid, prey, development, immature survival, reproduction*

INTRODUCTION

The quality of food has a direct impact on the growth, development and reproduction of insects. The study of food relationships of predaceous insects provides information on the

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nutritional quality of the food as well as the food choice (Omkar *et al*., 1997; Omkar & Pervez, 2001). Such studies on predaceous ladybeetles (Coleoptera: Coccinellidae) are important because of their economic value as biological control agents of phytophagous pests. The suitability of a prey species can be estimated by measuring its impact on biological attributes of the predator (Kalushkov & Hodek, 2001). Earlier studies showed that certain prey were highly nutritious as they increased the development and reproduction rates of predaceous ladybeetles (Hodek *et al*., 1984; Baumgärtner *et al*., 1987; Kalushkov, 1998; Kalushkov & Hodek, 2001; Omkar and Srivastava, 2003).

Hodek (1996) pointed out that a mere occurrence of ladybeetles at a prey-site cannot be a safe criterion for concluding that prey is a suitable food. The prey of ladybeetles have been classified as essential (which support both development and progeny production), alternative (which serve only as a source of energy and ensure survival but not reproduction) and rejected (which are non-palatable and hence rejected) (Hodek, 1996). Investigation of the food choice and suitability of prey to predaceous ladybeetles is of utmost importance, as it also provides valuable information for their effective utilization in the management of their prey populations in the field.

There are scarce records of food habits of the genus *Propylea*, with a little work on *Propylea quatuordecimpunctata* (L.) (Kuznetsov, 1975; Mills, 1981) and *Propylea japonica* (Thunberg) (Hukusima & Komada, 1972; Kawauchi, 1981), however, *Propylea dissecta* (Mulsant) has been totally ignored. *P. dissecta* is an aphidophagous ladybeetle of the Oriental region with adults abundant in the colonies of aphids, *viz. Aphis gossypii* (Glover) and *Aphis craccivora* Koch infesting *Lagenaria vulgaris* Seringe and *Dolichos lablab* L., respectively (Omkar & Pervez, 2000a). It can be sexed on the basis of patches present on head and pronotum (Omkar & Pervez, 2000b). Adult females of *P. dissecta* may withstand prey deprivation and can be reared on non-insect diets (Omkar & Pervez, 2003). *P. dissecta* exhibits three morphs, *viz*. pale, intermediate and typical with the pale morph being relatively more abundant (approx. 65% of adult population). This prompted us to select the pale morph of *P. dissecta* as an experimental model to investigate the prey-dependent growth, development, immature survival and adult reproduction. The investigation provides information on the most and least suitable (essential) prey amongst the seven aphid species tested and may be helpful in a bid to use *P. dissecta* as a biocontrol agent for its most suitable prey.

MATERIALS AND METHODS

Stock Maintenance

Adult individuals of the pale morph of *P. dissecta* collected from local agricultural fields were brought to the laboratory. Adult pairs were placed in separate glass beakers (height 11.0 cm and diameter 8.5 cm) and provided with one of the seven aphid species, *viz. A. gossypii*, *A. craccivora*, *Brevicoryne brassicae* Linnaeus, *Lipaphis erysimi* (Kaltenbach), *Myzus persicae* (Sulzer), *Rhopalosiphum maidis* (Fitch), and *Uroleucon compositae* (Theobald) infesting the twigs/pieces of leaves of *L. vulgaris* (bottle gourd), *D. lablab* (bean), *Brassica oleracea* L. (cabbage), *Raphanus sativus* L. (radish), *Solanum nigrum* L. (makoi), *Zea mays* L. (maize) and *Carthamus tinctorius* L. (safflower), respectively, as prey at 25 ± 2°C and 65 ± 5% R.H. Each prey species was provided in separate beakers. Adults mated frequently and the females oviposited.

Experimental Design

Larval and adult consumption of various aphid species by P. dissecta. Newly-hatched first instars of *P. dissecta* were placed in glass beakers (11.0×8.5 cm) (one instar per beaker) and daily supplied with 100 individuals of one of seven aphid species mentioned above until they moulted. The aphid species provided to the parental stock and that used as prey in the experiments were the same. The newly moulted second, third and fourth instars were daily provided with 100, 400, 400 individuals of different aphid species until the next moulting/pupation. Number of aphids consumed by each instar was recorded. Similarly, the newly emerged adult male and female ladybeetles were provided with 100 individuals of the different aphid species daily for their lifetime and their total prey consumption recorded. The experiment was replicated 10 times, i.e., 10 *P. dissecta* fed on each aphid species. The prey size was standardized to a limited extent by using early instars of big aphid species and later instars of small species. The gravid female aphids were not used.

Growth, development and immature survival of P. dissecta. Groups of 100 eggs of *P. dissecta* were obtained from the adults reared on seven different aphid species. These were placed in Petri dishes (100 eggs per Petri dish of size 16.0 × 2.6 cm) and incubated in an Environmental Test Chamber (ETC) maintained at 25 ± 2°C and 65 ± 5% R.H. Three observations per day were made to record egg hatching and the incubation period and number of first instars were recorded. All the neonates from each Petri dish were transferred individually into glass beakers, which were closed with muslin cloths. Each first instar was supplied only with the same aphid species as had been provided to its parental generation. The leftover aphids and host plant twigs were replenished daily. The duration and survival of different immature stages were recorded after respective ecdyses. Experiment was replicated 10 times (i.e., 10 replica of 100 *P. dissecta* eggs on each of the seven aphid species).

Percent immature survival (number of pupae × 100/number of first instars hatched), adult emergence (number of adults emerged × 100/number of pupae) and development rate (1/developmental period, i.e., the period in days from oviposition to adult emergence) were calculated for each prey species. The life stages (i.e., four instars, pre-pupa, pupa and adults (male and female)), which had been provided with the different prey species were weighed (0.1 mg precision) separately in 10 replicates ($n = 10$) using electronic balance (SARTORIUS-H51).

Reproductive attributes of P. dissecta *fed on each of seven aphid species.* To investigate the reproductive attributes of *P. dissecta* fed on seven aphid species, seven sets of newly emerged adult pairs ($n = 10$) were placed in glass beakers containing aphid prey (size of beaker and prey as above) and closed with fine muslin. Dried pieces of leaves and leftover aphids were replenished daily. Adult females, on attaining sexual maturity, mated frequently and oviposited. Pre-oviposition period, oviposition period, post-oviposition period, fecundity, percent egg viability and longevity of adult male and female ladybeetles were recorded.

Data Analysis

Data obtained on all ecological parameters of prey consumption, development and adult reproduction along with percent immature survival and adult emergence (in 10 replicates) from the above experiments were subjected to one-way ANOVA and comparison of means was made using Bonferroni's Test following a statistical package MINITAB on PC. The mean reproductive rate was calculated by taking the ratio of mean fecundity and mean oviposition period. Correlation analysis was applied to predict the relationships between: (i) development rate and weight of adults, (ii) the log weight of male and female, and (iii) longevity and fecundity of *P. dissecta*.

RESULTS

Larval and Adult Consumption of Various Aphid Species by *P. dissecta*

Prey consumption by larvae and adults varied significantly with prey species (Table 1). Individuals of *A. gossypii* were consumed in greatest numbers followed by *A. craccivora*, *L. erysimi*, *U. compositae*, *B. brassicae*, *R. maidis* and *M. persicae*. Prey consumption by first ($F = 26.88$; $P < 0.001$), second ($F = 21.36$; $P < 0.001$), third ($F = 40.89$; $P < 0.001$) and

TABLE 1. Prey consumed per individual by various predatory stages of *P. dissecta* on seven aphid species ($n = 10$)

	Aphid species							
Predatory stage	*A. gossypii*	*A. craccivora*	*L. erysimi*	*U. compositae*	*B. brassicae*	*R. maidis*	*M. persicae*	*F* value*
First instar	17.20 ± 0.57a	15.00 ± 0.45a	14.90 ± 0.71ab	14.20 ± 0.77b	16.70 ± 0.52a	11.50 ± 0.50c	8.90 ± 0.31d	26.88
Second instar	49.80 ± 1.40a	43.50 ± 1.33ab	41.20 ± 1.01b	40.00 ± 1.37b	39.50 ± 2.33b	34.00 ± 1.16c	29.00 ± 1.04d	21.36
Third instar	138.20 ± 2.84a	135.70 ± 2.30a	119.00 ± 2.29b	112.10 ± 4.72c	102.00 ± 3.01d	99.00 ± 2.85d	86.20 ± 2.32e	40.89
Fourth instar	176.00 ± 6.15a	170.70 ± 3.13a	152.50 ± 2.52b	143.20 ± 5.16c	141.00 ± 2.74c	131.00 ± 1.95d	102.30 ± 2.61e	43.92
Total larval	381.20 ± 7.11a	364.90 ± 5.42ab	327.60 ± 2.54b	309.50 ± 5.86c	299.20 ± 5.63cd	275.50 ± 3.20d	226.40 ± 3.05e	113.15
Adult male (total)	1902.90 ± 25.44a	1627.30 ± 16.41b	1452.80 ± 25.20c	1330.00 ± 36.78d	1164.70 ± 28.87e	1035.90 ± 21.54f	812.90 ± 16.92g	211.30
Adult female (total)	2012.00 ± 32.76a	1760.40 ± 16.55b	1532.10 ± 18.38c	1451.50 ± 30.73d	1357.70 ± 31.12e	1122.80 ± 35.03f	912.00 ± 16.26g	188.87

Values are Mean ± S.E.

* Mean values in the same row not followed by the same letter are significantly different at $P < 0.001$.

fourth ($F = 43.92$; $P < 0.001$) instars differed significantly leading to significant differences in total larval consumption ($F = 113.15$; $P < 0.001$). Total prey consumption by adult male ($F = 211.30$; $P < 0.001$) and female ladybeetles ($F = 188.87$; $P < 0.001$) also varied significantly in relation to prey species.

Growth, Development and Immature Survival of P. dissecta. The durations and weights of various life-stages of *P. dissecta* varied significantly when provided with different prey species (Table 2). The incubation period ($F = 32.98$; $P < 0.001$) and durations of first ($F = 12.89$; $P < 0.001$), second ($F = 8.54$; $P < 0.001$), third ($F = 20.18$; $P < 0.001$) and fourth instars ($F = 18.00$; $P < 0.001$), pre-pupa ($F = 21.54$; $P < 0.001$) and pupa ($F = 7.21$; $P < 0.001$) varied significantly with prey species. The total development periods of *P. dissecta* after feeding on different prey species varied significantly ($F = 52.93$; $P < 0.001$). The immature stages developed fastest (0.080 day^{-1}) when *A. gossypii* was provided as prey, whilst slowest (0.061 day^{-1}) on *M. persicae* (Table 3).

Weights of different predatory stages of *P. dissecta* varied significantly after feeding on different aphid species (Table 2). The wet weights of first ($F = 23.16$; $P < 0.001$), second ($F = 19.26$; $P < 0.001$), third ($F = 17.44$; $P < 0.001$) and fourth ($F = 93.98$; $P < 0.001$) instars varied significantly. The prey dependent wet weights of pre-pupae ($F = 81.39$; $P < 0.001$), pupae ($F = 91.91$; $P < 0.001$), adult males ($F = 72.01$; $P < 0.001$) and females ($F = 50.52$; $P < 0.001$) also differed significantly.

Prey-dependent percent immature survival ($F = 9.99$; $P < 0.001$) and percent adult emergence ($F = 12.80$; $P < 0.001$) were highest when *A. gossypii* was provided as prey, and lowest when *M. persicae* was provided (Table 3). Low SE values for percent immature survival and adult emergence were obtained, which may be attributed to the high sample number of individuals reared (10 replicates of 100 individuals). The female weight and the developmental rate on different aphid species when correlated resulted in a significant r value ($r = 0.98$; $P < 0.001$ (Figure 1a)). The same was found in the correlation of weights of female and male ladybeetle fed on the same prey species ($r = 0.98$; $P < 0.001$; Figure 1b).

Reproductive Attributes of P. dissecta *Fed on Various Aphid Species.* Reproductive attributes and adult longevity were found to be prey-dependent (Table 3). Significant variations in pre-oviposition period ($F = 4.99$; $P < 0.001$), oviposition period ($F = 61.82$; $P < 0.001$), post-oviposition period ($F = 23.20$; $P < 0.001$), fecundity ($F = 80.24$; $P < 0.001$), and egg viability (%) ($F = 30.27$; $P < 0.001$) were recorded after feeding on different prey species. The mean reproductive rate of the female ladybeetle was highest on *A. gossypii* and lowest on *M. persicae*. The longevity of male ($F = 13.30$, $P < 0.001$) and female ($F = 6.19$, $P < 0.001$) ladybeetles varied significantly in relation to prey species. Adults lived longest when *A. gossypii* was provided as prey, and shortest when *M. persicae* was provided. Correlation of longevity and fecundity resulted in significant r value ($r = 0.97$; $P < 0.001$; Figure 1c).

DISCUSSION

As all the seven prey species were consumed by the predatory stages of *P. dissecta* they can be used in laboratory rearings. Strikingly consistent effects of prey quality on prey consumption, development, immature survival, weights and adult reproduction of *P. dissecta* were recorded. Despite the small replicate size ($N = 10$), the differences in the life attributes of *P. dissecta* on seven aphid species were significant and consistent indicating the prominent difference in suitability.

The ecological attributes, signifying predator's fitness, were optimal using *A. gossypii* as prey. Suitability of prey species on development and adult reproduction of *P. dissecta* in a decreasing order was: *A. gossypii* > *A. craccivora* > *L. erysimi* > *U. compositae* > *B. brassicae* > *R. maidis* > *M. persicae*. *A. gossypii* is also an essential food for *P. japonica* (Hukusima & Komada, 1972) and *P. quatuordecimpunctata* (Kuznetsov, 1975). The results for *A. gossypii* may indicate its higher palatability by *P. dissecta* as compared to other aphid

TABLE 2. Duration (in days) and weight (in mg) of various life stages of *P. dissecta* on seven aphid species ($n = 10$)

Stage		Aphid species							
		A. gossypii	*A. craccivora*	*L. erysimi*	*U. compositae*	*B. brassicae*	*R. maidis*	*M. persicae*	*F* value*
Incubation period	Duration	2.29 ± 0.05a	2.35 ± 0.05ab	2.39 ± 0.05b	2.40 ± 0.05bc	2.42 ± 0.03c	2.79 ± 0.04d	2.90 ± 0.04e	32.98
First instar	Duration	1.65 ± 0.07a	1.74 ± 0.06b	1.75 ± 0.04b	1.77 ± 0.04bc	1.87 ± 0.07c	2.10 ± 0.03d	2.11 ± 0.04d	12.89
	Weight	1.63 ± 0.04a	1.57 ± 0.04ab	1.50 ± 0.06b	1.47 ± 0.05bc	1.33 ± 0.04c	1.12 ± 0.04d	1.10 ± 0.03d	23.16
Second instar	Duration	1.76 ± 0.06a	1.78 ± 0.12a	1.77 ± 0.08ab	1.83 ± 0.08b	1.90 ± 0.07c	2.21 ± 0.03d	2.31 ± 0.05e	8.54
	Weight	3.06 ± 0.07a	2.93 ± 0.14a	2.56 ± 0.16b	2.50 ± 0.11b	2.25 ± 0.13c	1.82 ± 0.08d	1.78 ± 0.08d	19.26
Third instar	Duration	1.38 ± 0.06a	1.64 ± 0.11b	1.78 ± 0.09c	1.85 ± 0.10c	1.88 ± 0.07c	2.39 ± 0.06d	2.41 ± 0.09d	20.18
	Weight	6.03 ± 0.15a	5.71 ± 0.24b	5.34 ± 0.26c	5.19 ± 0.24c	4.67 ± 0.25d	3.87 ± 0.17e	3.74 ± 0.14e	17.44
Fourth instar	Duration	2.15 ± 0.03a	2.26 ± 0.06ab	2.30 ± 0.04b	2.36 ± 0.05bc	2.46 ± 0.06c	2.72 ± 0.05d	2.82 ± 0.09d	18.00
	Weight	13.24 ± 0.22a	12.73 ± 0.37b	11.39 ± 0.28c	11.11 ± 0.18c	9.40 ± 0.24d	7.28 ± 0.21e	7.19 ± 0.21e	93.98
Pre-pupa	Duration	0.47 ± 0.01a	0.49 ± 0.01a	0.57 ± 0.02b	0.57 ± 0.02b	0.59 ± 0.03bc	0.73 ± 0.03c	0.81 ± 0.04d	21.54
	Weight	12.71 ± 0.22a	12.34 ± 0.37a	10.78 ± 0.29b	10.60 ± 0.18b	9.24 ± 0.22c	7.16 ± 0.23d	7.02 ± 0.21d	81.39
Pupa	Duration	2.73 ± 0.04a	2.83 ± 0.04b	2.86 ± 0.04b	2.86 ± 0.04b	2.88 ± 0.02b	3.00 ± 0.04c	3.05 ± 0.05c	7.21
	Weight	12.28 ± 0.18a	11.89 ± 0.36b	10.47 ± 0.30c	10.00 ± 0.15c	8.76 ± 0.21d	6.57 ± 0.21e	6.56 ± 0.21e	91.91
Development	Duration	12.43 ± 0.19a	13.10 ± 0.24b	13.43 ± 0.24bc	13.64 ± 0.18c	13.99 ± 0.17d	15.93 ± 0.12e	16.39 ± 0.29f	52.93
	Weight								
	Male	13.10 ± 0.44a	12.39 ± 0.28b	11.03 ± 0.29c	10.39 ± 0.27d	8.63 ± 0.17e	7.27 ± 0.22f	7.13 ± 0.21f	72.01
	Female	16.09 ± 0.43a	15.77 ± 0.43ab	14.94 ± 0.31b	13.76 ± 0.30c	12.74 ± 0.30d	10.12 ± 0.41e	10.09 ± 0.23e	50.52

Values are Mean ± S.E.
* Mean values in the same row not followed by the same letter are significantly different at $P < 0.001$.

TABLE 3. Ecological attributes of *P. dissecta* on seven aphid species ($n = 10$)

Aphid species	*A. gossypii*	*A. craccivora*	*L. erysimi*	*U. compositae*	*B. brassicae*	*R. maidis*	*M. persicae*	*F* value*
Immature survival (%)	77.10 ± 1.11a	74.08 ± 1.34ab	71.80 ± 1.47b	67.66 ± 1.94bc	67.22 ± 1.92c	65.26 ± 1.30cd	63.01 ± 1.87d	9.99
Adult emergence (%)	93.21 ± 0.79a	91.96 ± 0.86ab	88.87 ± 1.50bc	85.33 ± 0.98c	84.86 ± 0.99d	82.75 ± 1.46e	81.73 ± 1.79e	12.80
Developmental rate (per day)	0.080	0.076	0.074	0.073	0.071	0.063	0.061	–
Male longevity (in days)	57.10 ± 1.62a	55.50 ± 1.31a	51.10 ± 1.73b	48.00 ± 1.73bc	46.30 ± 1.45c	44.70 ± 1.30cd	42.50 ± 1.21d	13.30
Female longevity (in days)	62.40 ± 1.93a	58.40 ± 0.88ab	53.00 ± 2.60bc	51.90 ± 1.37c	51.00 ± 1.35cd	50.90 ± 2.26d	49.40 ± 2.32d	6.19
Pre-oviposition period (in days)	8.00 ± 0.60a	8.40 ± 0.34a	9.40 ± 0.67b	10.90 ± 0.92c	11.00 ± 0.98c	11.40 ± 1.26c	14.50 ± 1.58d	4.99
Oviposition period (in days)	50.30 ± 2.03a	44.80 ± 0.87b	34.00 ± 1.61c	29.00 ± 1.32c	27.00 ± 1.45cd	24.20 ± 1.30d	18.00 ± 1.40e	61.82
Post-oviposition period (in days)	4.10 ± 0.66a	5.20 ± 0.44a	9.60 ± 0.93b	12.00 ± 1.24c	13.00 ± 1.04c	15.30 ± 1.10d	16.90 ± 1.34d	23.20
Fecundity (in eggs)	856.00 ± 30.00a	750.00 ± 36.74b	506.00 ± 24.10c	456.80 ± 21.53d	414.00 ± 17.72de	374.60 ± 16.80e	212.00 ± 18.21f	80.24
Percent viability in eggs (%)	96.40 ± 0.31a	95.35 ± 0.38a	87.00 ± 1.35b	83.94 ± 1.73bc	81.16 ± 1.80c	76.09 ± 1.66cd	72.46 ± 2.81d	30.27
Mean reproductive rate (in eggs/day)	17.02	16.74	14.88	15.75	15.33	15.48	11.78	–

Values are Mean ± S.E.
*Mean values in the same row not followed by the same letter are significantly different at $P < 0.001$.

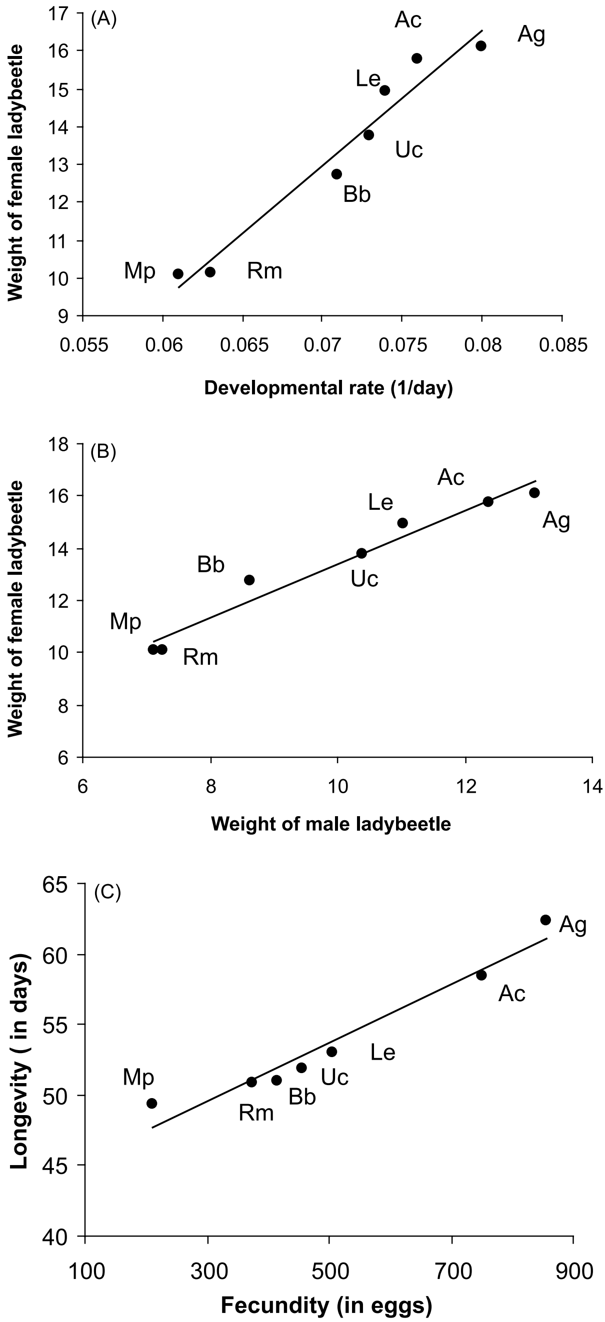

FIGURE 1. Relationships between (A) Weight of female ladybeetles and developmental rate, (B), Weights of female and male ladybeetles, and (C) female longevity and fecundity, for *P. dissecta* fed on seven aphid species, *viz. A. gossypii* (Ag), *A. craccivora* (Ac), *L. erysimi* (Le), *U. compositae* (Uc), *B. brassicae* (Bb), *R. maidis* (Rm), and *M. persicae* (Mp).

species. The varied palatability of different aphids may be attributed to the species-specific alkanes present on the surface of aphids (Liepert & Dettnere, 1996); and differences in the wax patterns of aphids could be used in the recognition and determination of palatability (Kosaki & Yamaoka, 1996). High prey consumption of *A. gossypii* may also be attributed to its nutrient contents, which probably ease digestion by *P. dissecta* as also reported in other ladybeetles (Atwal & Sethi, 1963; Francis *et al*., 2001).

M. persicae was least suitable as prey. It has been reported to be sublethal to *A. bipunctata* when infesting Brassicaceae (Francis *et al*., 2001). The probable toxic allelochemicals and metabolites of the host plant, *S. nigrum*, *via* the aphid food chain may possibly be responsible for the reduced consumption of *M. persicae* by *P. dissecta*. This interpretation appears to be in close agreement to that of Pasteels (1978) for *Adonia variegata* (Goeze) Emrich (1991) and Tripathi *et al*. (2000) for *C. septempunctata*. Decreased consumption of *M. persicae* and other less suitable aphids for growth and development of ladybeetle might also be due to sensory perception prior to attack and/or to previous bad experience. Certain alkaloids and unsuitable chemical constituents present in aphid species lead to reduced consumption and thereby decreased developmental rates of ladybeetles (Okamoto, 1966). Reduced consumption, in response to harmful chemicals in body contents of certain aphids, might maintain the unwanted chemicals below lethal levels and allow some survival of the ladybeetle. Biochemical studies of body contents of aphids are, therefore, needed to check the unsuitability of certain aphid species. Delay in the development of *H. axyridis* was reported as caused by starvation in absence of its preferred prey and despite the presence of other less suitable prey (Hukusima & Ohwaki, 1972).

Prey consumption increased with successive larval instars of *P. dissecta*. Neonates of ladybeetles are known to have a poor foraging capacity (Hemptinne *et al*., 1992; Dixon, 2000) with slow turning rates (Ponsonby & Copland, 2000), which cumulatively reduce their voracity. The lesser prey consumption by early instars of *P. dissecta* may also be attributed to their small size and slow crawling. The fourth instars were the most voracious amongst larval instars. The greater food requirement for their growth and development may be the reason for their increased prey consumption (Sharma *et al*., 1997). They have to attain critical weight for pupation (Ferran & Larroque, 1977). Adult females were more voracious than adult males, which may be attributed to their larger size (Kawauchi, 1979) and to their higher requirements of nutrients and energy resources for ovarian development and egg production. A greater quantity of diet enriched with nutrients was needed for the ovarian development of *Stethorus punctum* (LeConte) (Houck, 1991). The smaller males have lower dietary requirements. This may also be attributed to their active searching for mates.

The short incubation period of eggs after feeding the parents on *A. gossypii* may be a result of improved embryogenesis, because of the role of parental diet on the development of embryos. All instars developed fastest on *A. gossypii*. Consumption of *A. gossypii* also enhanced the development of immature stages of *Coccinella transversalis* Fabricius (Omkar & James, 2004). The other aphid species were relatively less suitable and consumed in lesser quantity, thereby resulting in delayed moulting/pupation.

Adult longevity of *P. dissecta* was prey-dependent and females lived longer than males. The increased longevity of females may be attributed to their relatively greater size, high food requirements and voracious feeding. They consume more number of prey than the males, which enhances their fitness against hostile environment. The males are smaller and more vulnerable to pathogenic or parasitic attacks (Majerus & Hurst, 1997). Also, females that lived longer produced more eggs than those having shorter life.

Consistency in the ranking of prey was evident in the wet weights of life stages of *P. dissecta* reared on seven aphid species. Life stages were heavier when reared on suitable aphid species. Weights of later life stages, *viz.* fourth instars, pupae and adults, varied more significantly than the earlier ones. This asymmetry in weights may be attributed to the relatively lesser prey consumption by the early instars, while fourth instar and the adults consume more prey, owing to the greater energy requirement for further growth and development. In *Scymnus levaillanti* Mulsant and *Cycloneda sanguinea* (Linnaeus), the fresh weight fell slightly at the time of moult, due to the loss of exuvium and some water, which was not immediately replaced because the larvae stop feeding (Isikber & Copland, 2001). Pre-pupae weighed more than pupae, owing to the weight loss by discarding the last larval exuvia. Slight dehydration as a metabolic cost during the transformation from prepupae to pupae is also a possible reason for the weight loss (Isikber & Copland, 2001; Omkar & Srivastava, 2003). Adult females were larger than males. The present study correlates adult weight with developmental rate of immature stages, suggesting that immature stages, which develop faster, should grow into heavier adults than those that develop slower. This agrees with the recent study on dietary requirements of *C. septempunctata* (Omkar & Srivastava, 2003).

The aphid species used in the present study were found to be essential food (Hodek, 1996) of *P. dissecta* with maximum suitability of *A. gossypii*, as it gave maximum reproductive output and reproductive period. Shortest pre-oviposition period was recorded in females of *P. dissecta* fed on *A. gossypii*, as also reported in *P. japonica* (Kawauchi, 1981). The longest oviposition period of females fed on *A. gossypii* may be ascribed to its high consumption, while the decreased consumption of less suitable food adversely affected the ovariole development (Honek, 1980). High fecundity of *P. dissecta* reared on more suitable aphid species was due to increased prey consumption leading to higher conversion of food into eggs (Baumgärtner *et al*., 1987; Rhamhalinghan, 1987) and vice-versa with less suitable aphid species. Decreased fecundity on less suitable prey may be ascribed to allelochemicals and secondary metabolites of host plants (Francis *et al.*, 2001). Percent egg viability of *P. dissecta* varied significantly with prey species and was maximum when adults were fed on *A. gossypii.* High consumption of suitable prey is known to increase the weight of eggs in other insects, which contained a large quantity of yolk and consequently increased egg viability (Simmons, 1988).

In conclusion, it can be inferred that: (i) *P. dissecta* is a generalist feeder and all seven aphid species tested are its essential foods, which support both development and adult reproduction, (ii) rank order of prey species was consistent in all experimental parameters, (iii) *A. gossypii* was most suitable for development and reproduction followed by *A. craccivora*, *L. erysimi*, *U. compositae*, *B. brassicae*, *R. maidis* and *M. persicae*, (iv) decreased prey consumption and low fecundity when fed on certain aphids, such as, *R. maidis* and *M. persicae* suggests that these can be used as substitutes to maintain *P. dissecta* in laboratory when the more suitable essential food is not available, (v) immature stages developing faster grew into heavier adults, and (vi) such females lived longer to produce more eggs. The information obtained from the present study can be helpful in the mass rearing of *P. dissecta* by enabling selection of the best food. The findings also support the possibility of utilizing *P. dissecta* for the biocontrol of *A. gossypii*.

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