J. Biosci., Vol. 16, Number 3, September 1991, pp 103–109. © Printed in India

Why do ladybirds (Coleoptera: Coccinellidae) cannibalize?

B K AGARWALA*
Department of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, England
*Present address: Department of Life Science, Tripura University, Agartala 799 004, India

MS received 16 March 1991; revised 19 August 1991

Abstract. Cannibalism of eggs by larvae of *Adalia bipunctata,* an aphidophagous species of ladybirds, is important for survival when aphids are scarce. Ladybirds survive longer by eating eggs of their own species rather than aphids. Since it costs less, in terms of larval growth, to eat eggs rather than aphids, cannibalism has a strong advantage under conditions of prey scarcity.

Keywords. Ladybirds; aphidophagous coccinellids; cannibalism.

1. Introduction

Fox (1975) reviewed cannibalism in animals. Several studies have recognized that the predatory species of ladybirds show cannibalism of eggs and larvae (Banks 1956; Dixon 1959; Kaddou 1960; Brown 1972; Dimetry 1974; Osawa 1989; Agarwala and Dixon 1990).

Dixon (1959) considered egg cannibalism of ladybirds as an artifact of laboratory rearing and, therefore, of little ecological significance. Mills (1988), however, showed that density-dependent egg cannibalism of 6–30% occurred in *Adalia bipunctata* (L.) in the field. Osawa (1989) recorded that sibling and non-sibling cannibalism occurred throughout the oviposition period of *Harmonia axyridis* Pallas in the field.

The reproductive strategy of aphidophagous ladybirds has probably been adapted to the seasonality of aphid incidence. As a consequence, ladybirds are reproductively active for short periods when host plant quality favours population build-up of aphids (Hemptinne and Dixon 1991).

Ladybirds lay eggs in the vicinity of a high concentration of aphids (Dixon 1959) which enables the new born larvae to eat young aphids. Any interference in the form of intraspecific competition and/or population collapse of aphids may result in cannibalism in the larvae of ladybirds which are under tremendous pressure to complete development.

In this paper the conditions which favour cannibalism in ladybirds are examined.

2. Materials and methods

Adults of *A. bipunctata* were collected from the field in the summer of 1989 in eastern England and used for raising stock cultures in the laboratory at 20° C and a 16 h photoperiod. Rectangular plastic boxes (922 × 13 × 9 cu cm) were used to keep the adults and were provided with corrugated paper to facilitate the laying of eggs. Water-soaked tissue paper, fresh leaves of *Vicia faba* and plenty of fresh pea aphids, *Acyrthosiphon pisum* (Harris) were also provided. Pea aphids were obtained from a large culture developed on *Vicia faba* in the green house. A large culture of

ladybirds was maintained throughout the period of study to achieve the specific requirements of each of the experiments reported here.

Egg cultures were separated from the boxes at 2-day intervals and kept, one cluster each, in a 9 cm diameter Petri dish at 20° C and a 16 h photoperiod. Newborn first instar larvae were transferred, 4–6 in number, to another 9 cm diameter Petri dish and offered adequate freshly obtained pea aphids at 2-day intervals until pupation.

Experiments were carried out in a clean, dry 5 or 9 cm Petri dish at 20° C and a 16 h photoperiod. Each of the experimental larvae was starved for 24 h prior to an experiment in order to induce the same level of hunger. Fourth instar and younger larvae of ladybirds were respectively offered fourth instar and second instar nymphs of aphids as food. Eggs of *A. bipunctata* were used as food wherever required. Fresh to dry weight conversion ratios were obtained by drying at 37° C for 6–10 days until constant weight.

2.1 *Do ladybirds eat eggs in the presence of prey?*

Two-day old fourth instar larvae were offered low (4), moderate (28) and high (44) quantities of fourth instar aphids. The choice of the number of aphids offered was tentative and approximately corresponded to the respective level of aphid infestation usually prevalent in the field. In addition, the ladybird larvae were provided with a cluster of 20 eggs (2-day old). Twenty of these larvae were tested at each aphid density. The number of eggs or aphids consumed was recorded after 1, 5 and 24 h.

2.2 *Do ladybirds differ in their daily feeding capacity on eggs and aphids?*

Two-day old first, second, third and fourth instar larvae were each offered an equal quantity of eggs (1–2-day old) and aphids (second instar nymph) by fresh weight. Twenty of these larvae of each instars were tested for 24 h to record the mean quantity of eggs and aphids eaten.

2.3 *Do ladybirds have the same duration of survival by eating either eggs or aphids?*

To determine this, individuals of similar age of each of the four larval instars of *A. bipunctata* were offered a fixed quantity of aphids (second instar nymphs) or eggs by fresh weight. Twenty of the larvae of each instars were tested and the length of time for which they survived after feeding was noted.

2.4 *Can larvae of A. bipunctata eat eggs and aphids with equal efficiency?*

This was determined by offering 2-day old fourth instar larvae an equal quantity of eggs (1–2-day old) or aphids (fourth instar nymphs) by fresh weight. Twenty such larvae were tested for the amount of eggs or aphids eaten.

2.5 *Relative nutritive values of eggs and aphids*

To determine this, 1-day old fourth instar larvae were fed a known weight of eggs

(16·56 mg) and second instar of aphids (48 mg) over 4 days. The quantities of the two foods needed to support similar growth rates were determined. The comparisons were made on a dry weight basis. Twenty of the fourth instar larvae were used to test the cost associated with eating aphids.

2.6 *Is cost the same by eating eggs of different age?*

To determine this, individual 1-day old first instar larvae were offered 1- or 4-day old eggs in a 5 cm diameter Petri dish in equal weights (0·40 mg). Twenty of the first instar larvae were tested for 24 h. Comparison was made on dry weight basis in terms of increase in weight of larvae.

3. Results

3.1 *Do ladybirds eat eggs in the presence of aphids?*

Egg cannibalism occurred at all aphid densities but was more pronounced at lower densities. The number of eggs eaten at aphid density 4 was significantly more than at 28 after 1, 5 and 24 h and one at 28 was significantly more than that at 44 after 24 h (table 1). Lower cannibalism at higher aphid density possibly resulted from a decline in the chances of encountering eggs as aphid density increased.

3.2 *Do ladybirds differ in their daily feeding capacity on eggs and aphids?*

Growing larvae of ladybirds show a gradual increase in their daily feeding capacity of aphids (Agarwala *et al* 1988).

In the present experiment the daily feeding capacity of all the four instars of larvae was significantly higher on aphids than eggs (table 2). Discernible variations were noticed between the larvae of different instars in their choice of eggs and aphids (figure 1). Older larvae ate proportionately more aphids than eggs compared to younger larvae.

Table 1. Mean number of eggs eaten at low (4), medium (28) and high (44) aphid densities by fourth instar larvae of *A. bipunctata* after 1, 5 and 24 h at 20°C.

Period after (h)	Mean no. of eggs eaten at aphid densities		df	*t**	*P*
I	Low (4)	Medium (28)			
	M SD	M SD			
1	2·45 ± 0·58	1·04 ± 0·25	38	4·0	< 0·001
2	8·57 ± 1·53	2·90 ± 0·96	38	7·87	< 0·001
24	17·95 ± 0·76	6·70 ± 1·37	38	22·90	< 0·001
II	Medium (28)	High (44)			
	M SD	M SD			
1	1·04 ± 0·25	0·87 ± 0·12	38	1·95	NS
5	2·90 ± 0·96	2·75 ± 1·01	38	0·30	NS
24	6·10 ± 1·37	5·20 ± 1·43	38	3·35	< 0·002

**t* test for paired samples; NS, Not significant.

Table 2. Mean quantity of aphids or eggs eaten by a 2-day old first, second, third and fourth instar larva in a day at 20° C.

Larval instars	Mean quantity eaten (mg) Eggs M SD	Aphids M SD	df	*t**	*P*
I	0·403 ± 0·01	1·72 ± 0·26	19	12·65	< 0·001
II	0·979 ± 0·05	3·71 ± 0·86	19	9·76	< 0·001
III	2·465 ± 0·43	8·76 ± 1·02	19	11·51	< 0·001
IV	3·993 ± 0·78	12·13 ± 3·58	19	32·39	< 0·001

**t* test for paired samples.

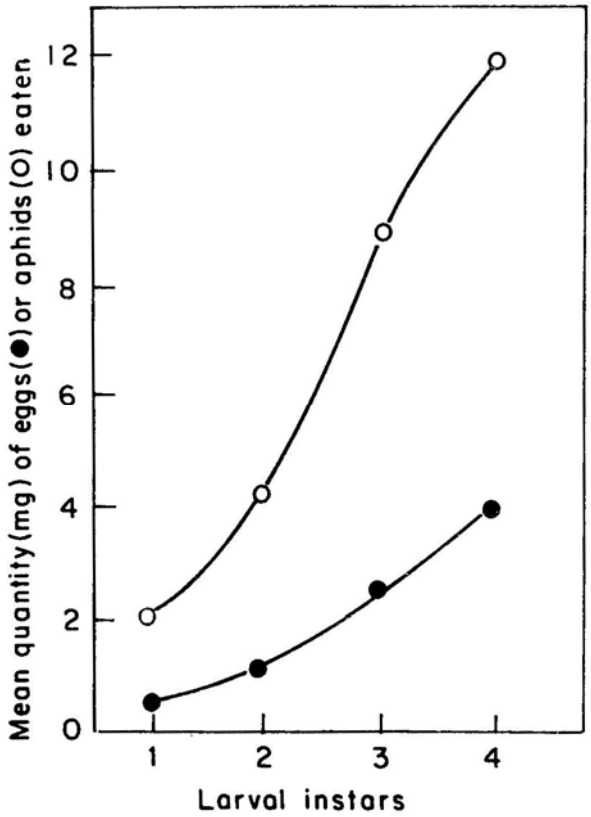

Figure 1. Variations in the choice of eggs and aphids eaten (Y) by the first (1), second (2), third (3) and fourth (4) instar larvae (X) of *A. bipunctata* after 24 h at 20°C.

3.3 *Do ladybirds have the same duration of survival by eating either eggs or aphids?*

Food affects the duration of developing larvae (Hukusima and Kouyama 1974). Duration of survival is linked to the nutrition value of the acceptable food.

Larvae of all the four instars survived significantly longer by feeding on eggs than aphids when given in equal quantities by fresh weights (table 3). This clearly indicates that eggs offer higher nutrition compared to aphids.

Table 3. Duration of survival in first, second, third and fourth instars larvae of *A. bipunctata* by feeding equal quantities (weight) of eggs and aphids at 20°C.

Larval instars	Food quantity	Mean duration of survival: Eggs M SD	Mean duration of survival: Aphids M SD	df	*t**	*P*
I	1·4	6·15 ± 0·59	3·85 ± 0·87	19	9·114	< 0·001
II	2·5	6·13 ± 0·91	4·80 ± 0·76	19	4·65	< 0·001
III	4·0	5·85 ± 1·46	4·60 ± 0·94	19	3·10	< 0·001
IV	4·7	11·95 ± 1·05	5·75 ± 0·72	19	23·99	< 0·001

*t test for paired, samples.

Table 4. The total quantity of aphids and eggs supplied, mean quantity eaten and not eaten by a fourth instar larva of *A. bipunctata* in 24 h at 20°C.

Food	Total quantity (mg)	Mean quantity (mg): Eaten M SD	Mean quantity (mg): Not eaten M SD
Eggs	4·85	4·68 ± 0·72	0·17 ± 0·04
Aphids	4·91	4·17 ± 0·12	0·74 ± 0·03
df	19	19	19
*t**	1·09	4·74	6·03
P	NS	< 0·001	< 0·001

**t* test for paired samples

3.4 *Can larvae of A. bipunctata eat eggs and aphids with equal eficiency?*

Having found that larvae of ladybirds show no inhibition in eating eggs it was tested whether larvae can use aphids with equal efficiency.

After 24 h a fourth instar larva used a significantly higher quantity of eggs than aphids (table 4). Most of the eggs were eaten in whole, and a few seem to have been bitten by the action of mandibles which possibly resulted in the loss of a little amount of egg-yolk. In the case of aphids, the non-used amount consisted of appendages and, in some cases, head, including rostrum.

3.5 *Relative nutritive value of eggs and aphids*

Ladybirds do not lay unlimited eggs. Therefore, it was natural to know the cost associated with eating eggs.

Fourth instar larvae required a much greater biomass of aphids than eggs for a similar growth rate (table 5). This clearly shows that it costs less to eat eggs in terms of larval growth.

3.6 *Is cost of eating eggs of different age the same?*

Eggs of *A. bipunctata* have an incubation period of 5–6 days at 20° C and a 16 h

Table 5. Mean quantity of eggs and aphids by fresh and dry weights eaten and growth rate achieved over 4 days by fourth instar larvae of *A. bipunctata* at 20°C.

Food	Mean quantity given (mg)	Mean weight eaten (mg)		Growth rate of larvae (mg/day)
		Fresh weight M SD	Dry weight M SD	M SD
Aphids	48·0	43·6 ± 0·69	8·4 ± 0·15	1·7 ± 0·3
Eggs	16·56	15·7 ± 0·50	2·5 ± 0·10	1·7 ± 0·3
df		38	38	38
t*		69·4	77·0	0·1
P		< 0·001	< 0·001	NS

*t test for paired samples NS, Not significant.

Table 6. Increase in fresh and dry weights of 1-day old first instar larvae of *A. bipunctata* after 24 h when provided with 1- and 4-day old eggs in equal quantity by weight.

Age of eggs	Increase in weight (mg)	
	Fresh weight M SD	Dry weight M SD
1-day old	0·31 ± 0·09	0·073 ± 0·012
4-day old	0·14 ± 0·05	0·048 ± 0·07
df	19	19
t*	6·79	4·12
P	<0·001	<0·001

* t test for paired samples

photoperiod. First instar larvae, soon after hatching, are the potential predators to encounter eggs of different age.

There was a significantly higher increase in the dry weight of the first instar larva by eating 1day old eggs than 4-day old eggs (table 6). This indicates that it costs more to eat older eggs containing embryos and, therefore, they are preferred less when compared to 1day old eggs which largely contain the egg-yolk.

4. Discussion

The results reported here suggest that larvae of ladybirds will cannibalize eggs in the presence of aphids but the intensity of cannibalism is greater when aphids are scarce (table 1). This implies that the occurrence of cannibalism is possibly linked to the chances of encountering eggs in relation to aphids. At higher aphid density, less cannibalism is linked to a higher encounter of aphids than eggs which are immobile and defenceless.

Although the daily feeding capacity of eggs in all the four instars of ladybird larvae is much less compared to that on aphids (table 2), larvae show a higher duration of survival on eggs (table 3). Survival of new-born larvae of ladybirds is much dependent on the abundance of young aphids. Young larvae must complete development before aphid population collapses. In the event of aphid population collapse, larvae are under tremendous pressure to survive on alternate food.

Unhatched eggs in the patchy habitat of ladybirds are the easy targets. Thus conditions favouring aphid scarcity also promote cannibalism in ladybirds. A cannibalizing larva not only improves its chances of survival but also eliminates potential competitors. Fresh eggs, being more nutritive, are preferred to the older eggs when conditions favour cannibalism (table 6).

Although the level of egg cannibalism by ladybirds is low when aphids are abundant, nevertheless, cannibalism occurs in the field (Mills 1988; Osawa 1988). It is, therefore, not surprising that a ladybird larva eats eggs more efficiently than aphids (table 4). Since it costs less to eat eggs than aphids in terms of larval growth (table 5), egg cannibalism would be a distinct advantage to ladybirds even at higher prey density.

Circumstances which shape the attack strategy of ladybirds in the selection of food are little understood. Being predators, ladybirds are expected to orient their attack on target food by assessing its availability. One of the possibilities is to prefer larger and assured food supply for themselves and their offspring rather than to go for smaller and unsure availability of eggs at higher prey density. This behaviour is likely to increase their fitness under natural conditions.

Thus, cannibalism is important for survival when aphids are scarce. Ladybirds, however, should first locate aphids to ensure adequate food availability for their own reproductive needs and their offspring.

References

Agarwala B K, Das S and Sen Chowdhuri M 1988 Biology and food relations of *Micraspis discolor* (F.): an aphidophagous coccinellid in India; *J. Aphidology* **2** 7–17

Agarwala B K and Dixon A F G 1991 Cannibalism and interspecific predation by ladybirds; in *Ecology of Aphidophaga* (eds) A F G Dixon and I Hodek (Budapest: Academia) (in press)

Banks C J 1956 Observations on the behaviour and mortality in Coccinellidae before dispersal from the egg shells; *Proc. R. Entomol. Soc. London* **A31** 56–60

Brown H D 1972 The behaviour of newly hatched coccinellid larvae (Coleoptera: Coccinellidae); *J. Entomol. Soc. South Afr.* **35** 149–157

Dimetry N Z 1974 The consequences of egg cannibalism in *A. bipunctata* (Coleoptera: Coccinellidae); *Entoinophaga* **19** 445–451

Dixon A F G 1959 An experimental study in the searching behaviour of the predatory coccinellid beetle *Adalia decempunctata* (L.); *J. Anim. Ecol.* **28** 259–281

Fox L R 1975 Cannibalism in natural populations; *Annu. Rev. Ecol. Syst.* **6** 87–106

Hemptinne J L and Dixon A F G 1991 Why ladybirds have generally been so ineffective in biological control; in *Ecology of Aphidophaga* (eds) A F G Dixon and I Hodek (Budapest: Academia) (in press)

Hukusima S and Kouyama S 1974 Life histories and food habits of *Menochilus sexmaculatus* Fabricius (Coleoptera: Coccinellidae); *Res. Bull. Fac Agric. Gifu Univ.* **36** 19–20

Kaddou I 1960 The feeding behaviour of *Hippodamia quinquesignata* (Kirby); *Univ. Calif. Publ. Entomol.* **16** 181–232

Mills N J 1988 Voracity, cannibalism and coccinellid predation; *Ann. Appl. Biol* **101** 144–148

Osawa N 1989 Sibling and non-sibling cannibalism by larvae of a ladybeetle *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) in the field; *Res. Popul. Ecol.* **31** 153–160