Survival and fecundity of Adalia bipunctata (Coleoptera, Coccinellidae) and some other predatory insect species on an artificial diet and a natural prey

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One group of *Adalia bipunctata* (L.) was kept throughout its life on *Myzus persicae* (Sulzer) (Mp), a second group on an artificial diet (Ad), a third as larvae on Mp and as adults on the Ad and fourth as larvae in the Ad and as adults on Mp.

The larval mortality on the Ad was about four times that on Mp. The postembryonic development on the Ad took about 40 % longer than on MP. The mean adult weight at emergence on the Ad was about 83 % of the weigth on Mp.

The egg-laying performance and the hatchability of the eggs in the different groups was chiefly determined by the adult diet, but the larval diet also had a minor effect.

Some other predatory insect species also developed into adults on the artificial diet: *Chrysopa carnea* Stephens, *Hippodamia 13-punctata* (L.), *Propylaea 14-punctata* (L.), *Coccinella transversoguttata* Fald. and *C. 7-punctata*. Three of the twenty-five *C. 7-punctata* females even laid fertile eggs on the artificial diet.

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Among the few artificial diets for predatory insects, the only one on which a coccinellid species can be reared for generations seems to be the diet for *Coleomegilla maculata* (De Geer) developed by Atallah & Newsom (1966). Kariluoto et al. (1976) developed a wheat germ diet for *Adalia bipunctata* (L.) based on the diet for *C. maculata*. This diet was further modified by Kariluoto (1978) in an attempt to obtain the ideal concentrations of two fungicides in the diet. In this paper the new artificial diet (Ad) is compared with a natural prey, *Myzus persicae* (Sulzer) (Mp), with special reference to the survival and egg-laying of *A. bipunctata* females. Some other predatory insect species were also reared on the Ad with varying success.

The stock population of *A. bipunctata* was collected in the Helsinki area on autumn 1977 and stored in total darkness at +5° C until taken into room temperature for egg-laying. The beetles were fed ad libitum on Mp on *Capsicum* pepper leaves. The adults were kept in batches of about 20 in jars with a diameter of 160 mm and a height of 90 mm. The experiments were started in October and continued to the end of March in the following year. In the experiments the larvae and adults were kept at +25±0.5° C in a light:dark cycle of 18:6 h. The antifungal agents in the Ad, sorbic acid and methyl-p-hydroxybenzoate, were used at concentrations of 1250—750 ppm and the amounts were dissolved in 5 ml of EtOH abs. The larvae on the Ad were reared individually in 4-ml vials, but those on Mp in 20-ml vials. It was easier to put the living aphids into bigger vials and the smaller vials needed less Ad. In preliminary experiments the difference in the sizes of the vials was not found to have any effect on the developmental periods, postembryonic mortality, or the adult emergence weights or rates of *A. bipunctata*. The larvae emerging from an egg-cluster were divided in two groups, one of which was put on to the Ad and the other on to Mp.

The pupae were transferred from the vials to empty vials with a soft, moist brush. The duration of postembryonic development and the adult emergence weight were recorded for every beetle. The adults kept as larvae on Mp were divided into two groups, one of wich was provided with Mp and the

Table 1. Development, sex ratio and fertility of eggs laid by the egg-laying proportion of females in *A. bipunctata* on different combinations of diets.

Larval-adult diets	Mp-Mp	Ad-Mp	Mp-Ad	Ad-Ad
Number of I instar larvae in expt	80	120	100	200
Adult emergence %	95	76.7	93	75.5
Survival % at start of egg-laying	91.3	80.8	85	67.5
Sex ratio (♀♀ %) at emergence	60.5	60.9	57.0	62.9
% of fertile ♀♀ in total of ♀♀ emerged	89.1	80.4	58.5	49.5
Hatching potential of eggs as %	74.2	61.8	33.4	30.6

other with the Ad. The adults kept as larvae on the Ad were divided in the same way, so that four adults groups with different feeding programs were reared separately for breeding. The agar and half of the water were omitted from the Ad for adults. A small piece of cotton lightly touched with the Ad was given to the adults of the two groups, while Mp was given to the other two groups. The adults in a diet group emerging on successive dates were taken daily as subgroups, which were placed in their own jars for breeding. The adults in a jar were separated in numbered 20 ml vials after the first eggs were found in a jar. These eggs were considered to belong to the first female to lay eggs after the separation. Every dead beetle was dissected and sexed. For further details of the rearing procedure, see KARILUOTO (1978).

Only females were followed in detail. The egg-number, preoviposition and egg-laying periods and survival rates were recorded. The eggs were counted and removed daily, when the beetles were fed. Once a week the hatching potentials were checked with all the eggs found that day. The eggs were allowed to hatch at +25° C in a chamber, in which a RH of 83 % was maintained by using a saturated KCl solution. Only the hatching percentages were recorded.

Other species used for experiments were *Adalia 10-punctata* (L.), *Coccinella 7-punctata* L., *C. 5-punctata* L., *C. transversoguttata* Fald., *Hippodamia 13-punctata* (L.), *Propylaea 14-punctata* (L.) and *Chrysopa carnea* Stephens. *C. transversoguttata* and *H. 13-punctata* were from Winnipeg, Canada. The other species were collected at the same time and same area as the *A. bipunctata* adults and stored in the same way. All the animals were reared under the same conditions as *A. bipunctata*, except the adults of *C. carnea*. These were reared on Food Wheast (HAGEN & TASSAN 1970) in acrylic cylinders (Ø 30 cm, h 20 cm). The data were subjected to the analysis of variance, and Tukey's studentized range test (P=0.05) was used to assess the significance of the differences between the means.

Postembryonic mortality

The first effects of the different larval diets are clearly seen in the postembryonic mortality of *A. bipunctata* (Table 1), which was nearly four times as high on the Ad as on Mp. The difference is highly significant (P=0.001). BLACKMAN (1965) has found similar differences in the mortality of *A. bipunctata* larvae reared on different aphid species: on *Aphis fabae* Scopoli 27.6 %, on *A. sambuci* L. 25.0 %, but on *M. persicae* (Mp) 17.8 % (+20° C, L:D 16:8 h). In *Adonia 11-notata* Schn. the mortality during postembryonic development on *A. fabae* (+25° C) was about 7 %, but on *A. nerii* Kalt. it was 34 % and on the eggs of *Anagasta kuehniella* Z. as high as 67 % (IPERTI & TREPANIER-BLAIS 1972).

As there were no statistically significant differences between the sex ratios of emerging adults reared previously on the Ad and on Mp (Table 1), it is unlikely that the mortality on the Ad during postembryonic development was sex selective.

Postembryonic development

The difference between the times required for postembryonic development in *A. bipunctata* is highly significant: 13.6 days on Mp and 18.9 days on the Ad (Table 2), i.e., 38.6 % longer on the Ad. On *A. fabae* and *A. sambuci* the retardation in the larval development was 25.0—28.8 % (Mp as control; BLACKMAN 1965). In *A. 11-notata* the retardation in the postembryonic development was about 54 % on *A. nerii* and on the eggs of *A. kuehniella*, as compared with development on *A. fabae* (IPERTI & TREPANIER-BLAIS 1972). The larval period of *A. bipunctata* on *Tetranychus urticae* Koch was 82 % longer than on the aphid *Coloradoa rufomaculata* (Wilson) (PUTMAN 1957).

Adult emergence weight and wing deformation

The difference in the mean weights of *A. bipunctata* adults at emergence (Table 2) is also highly significant, the reduction of weight on the Ad is 16.7 %. On *A. fabae*

Table 2. Development of some predatory insect larvae on an artificial diet (Ad) and on a natural prey, *Myzus persicae* (Mp) at +25° C. Data subjected to analysis of variance, significance levels of differences between the means (± S.E.M. as follows: *** P=0.001, NS not significant. — not recorded or tested.

Species		Number of larvae tested and adults obtained larvae	adults	%	Developmental period in days larval	pupal	larval+pupal	Adult wt at emergence in mg
Adalia bipunctata	Ad	320	243	75.9	—	—	18.9±0.2	7.53±0.10
	Mp	180	169	93.9	—	—	13.6±0.1	9.04±0.11
					—	—	496.4***	106.4***
Coccinella 7-punctata	Ad	139	46	33.1	24.0±0.4	4.2 ±0.1	28.2±0.4	15.98±0.44
	Mp	20	18	90.0	11.3±0.4	4.2 ±0.1	15.5±0.4	30.23±1.51
					280.6***	0.63NS	285.6***	147.2***
C. transversoguttata	Ad	12	4	33.3	32.2±1.3	5.7 ±0.3	38.0±1.2	13.07±0.94
	Mp	10	8	80.0	14.3±0..4	5.6 ±0.8	19.9±1.0	26.90±0.82
					134.5***	0.16NS	117.0***	106.1***
Hippodamia 13-punctata	Ad	42	27	66.7	20.5±0.6	4.7 ±0.1	25.2±0.6	—
	Mp	—	—	—	—	—	—	—
					—	—	—	—
Propylaea 14-punctata	Ad	32	27	84.4	12.4±0.3	2.8 ±0.1	15.2±0.3	4.96±0.23
	Mp	—	—	—	—	—	—	—
					—	—	—	—
Chrysopa carnea	Ad	25	20	80.0	15.1±0.4	8.8 ±0.3	23.9±0.5	—
	Mp	10	9	90.0	10.7±0.4	8.3 ±0.4	19.0±0.6	—
					42.3***	0.56NS	29.7***	—

and *A. sambuci* the retardation is about 32 % (Mp as control; Blackman 1965).

Though deformed elytra were found in some adults reared on the Ad and Mp, all the adults were normally coloured (cf. Kariluoto et al. 1976).

Hatching potentials of eggs

The hatchability of the eggs depended not only on the adult diet but also on the larval diet (Table 1). In every group of females the hatching potentials dropped towards the end of the egg-laying period. Differences in the fertility of eggs were also recorded by Blackman (1967) when *A. bipunctata* was reared on Mp (89.4 %) and on *A. fabae* (55.9 %).

Egg-laying

Data on the egg-laying are given in Table 3. Fecundity is chiefly determined by the adult diet, but the larval diet also has some influence. The part played by the larval diet was also noted by Rajamohan & Jayaraj (1973) while rearing *Menochilus 6-maculatus* (F.) on four different aphid species. El Hariri (1966), however, suggests that the fecundity of *A. bipunctata* females is entirely dependent on the kind of food they receive in adult life, and Blackman (1965, 1967) came to the same conclusion.

The females in the groups Mp-Mp and Ad-Mp show a clear maximum in their egg production at the beginning of the egg-laying period (Figure 1), whereas the groups Mp-Ad and Ad-Ad have no clear initial maximum. The high peak in the egg production of Ad-Ad females at the age of about 95 days is a consequence of the fact that many postovipositing females had died and the few remaining females had just begun to lay eggs or laid their highest egg numbers at this late age. The well-fed, or suitably fed, females on Mp exhaust themselves sooner during egg-laying than the badly or unsuitably fed females on the Ad (Table 3, Fig. 1).

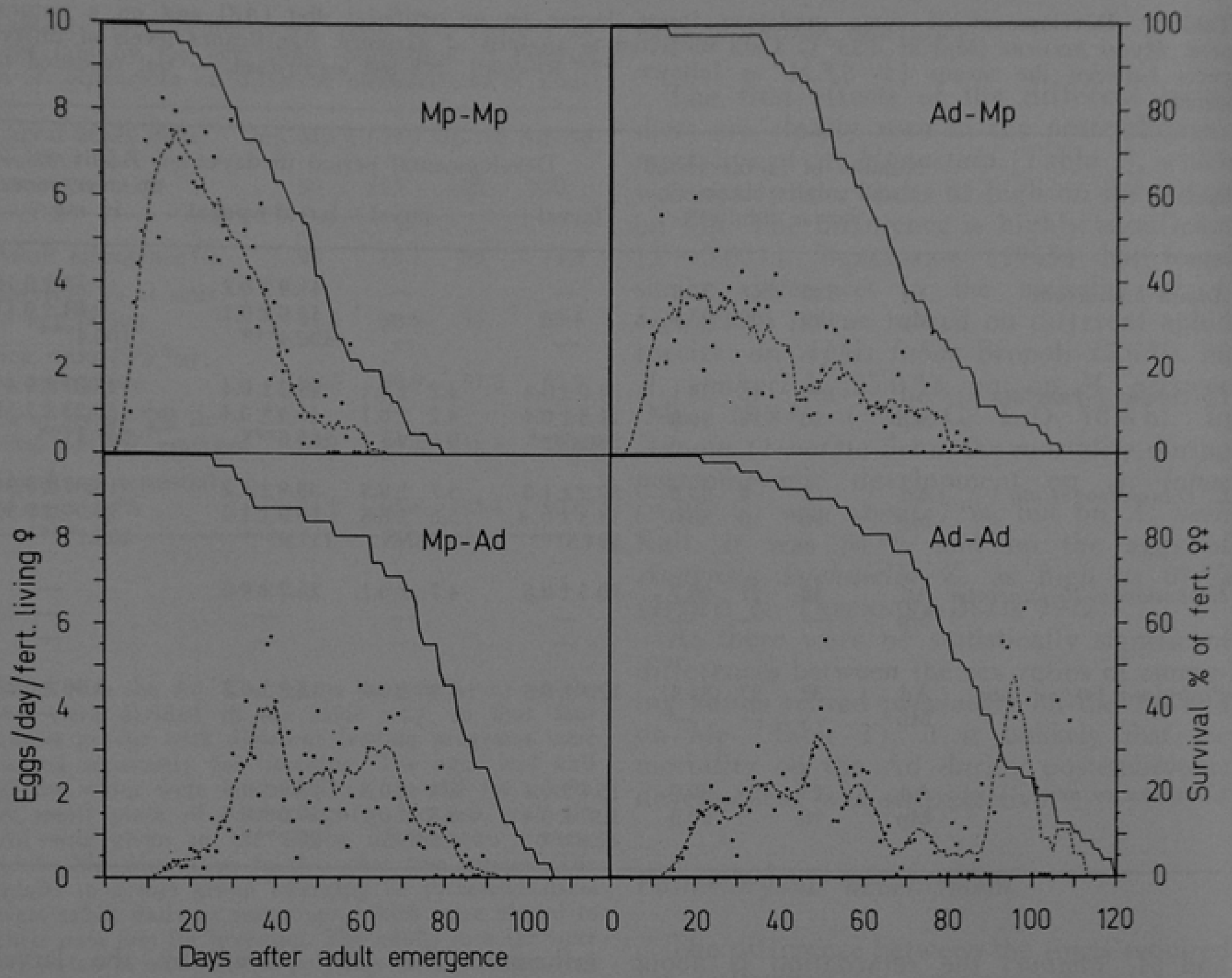

Fig. 1. Mean daily egg-numbers and survival percentages of fertile *A. bipunctata* females on different diet combinations (see text). Black spot=daily mean number of eggs/living female; broken line=seven days' sliding mean of daily means; solid line=survival of fertile females.

Other predatory species

Hodek (1973) reports (p. 131) that *Coccinella* spp. are rather difficult to rear on artificial diet, and Smith (1965) did not succeed in rearing three *Coccinella* spp. on dried aphids of three species that are their normal prey. The observations of these authors are supported by a comparison of the rearing results for *A. bipunctata* on the Ad with the results for *C. transversoguttata* and *C. 7-punctata*. When *A. bipunctata* larvae are reared on the Ad, the time needed for postembryonic development is about 38.6 % longer than on Mp, but in *C. transversoguttata* the time on the Ad is 91.2 % longer than on Mp and in *C. 7-punctata* 82.7 % longer (Table 2).

Three of the 25 *C. 7-punctata* females kept on the Ad laid a total of 22 eggs after a preoviposition period of five to seven weeks. Seven of the eggs hatched and two small adults emerged after long developmental periods (♂ 35 days, 6.39 mg, ♂ 32 days, 8.94 mg).

Adults of *A. bipunctata* reared as larvae on the Ad weigh about 83.3 % of the controls on Mp. In *C. 7-punctata* the corresponding percentage is 52.9 and in *C. transversoguttata* 48.6. When *A. bipunctata* adults reared on the earlier modifications of the artificial diet weighed about 50 % of those on Mp, they were not seen copulating (Kariluoto et al. 1976). Later, on better modifications the adults weighed nearly 80 % of those on Mp and they began to copulate, but laid eggs only when fed on Mp.

Table 3. Egg-laying and survival of *A. bipunctata* females on different combinations of diets. Mp= *M. persicae*, Ad=artificial diet. Means (± S.E.M.), within each row not followed by the same letter are significantly different at the 0.05 level of probability according to Tukey's studentized range test.

Larval-adult diets Number of adults	Mp-Mp 41	Ad-Mp 45	Mp-Ad 31	Ad-Ad 47
Preoviposition period in days	8.0 a ± 0.4	14.6 b ± 1.2	18.4 c ± 0.7	20.5 c ± 0.3
Duration of egg-laying in days	30.7 a ± 2.1	53.3 b ± 2.7	59.4 bc ± 3.8	67.6 c ± 3.6
Survival of egg-laying ♀♀ in days	46.1 a ± 2.6	65.3 b ± 3.0	73.4 bc ± 3.9	80.9 c ± 3.4
Eggs/egg-laying female	180.4 a ±28.1	141.2 ab ±14.9	113.1 b ±14.7	108.0 b ± 9.8

H. 13-punctata and *P. 14-punctata* were not reared on aphids at all, but the adult emergence percentages on the Ad were promisingly high (Table 2).

Some larvae of *A. 10-punctata* and *C. 5-punctata* also developed into adults, their adult emergence percentages were very low and development slow.

The diet developed by SMIRNOFF (1958) gave poor results when it was fed to larvae of *A. bipunctata* and *C. 7-punctata*. Some larvae developed to the second instar in *A. bipunctata* but none in *C. 7-punctata*. SMIRNOFF (1958) reported that the adults of some coccinellid species lived longer on his diet than on a natural diet. Similar observations were made in this study. At least in *A. bipunctata* females the less suitable diet given to larvae and adults seems to prolong the mean life span significantly (Table 3).

Though it has frequently been possible to rear *A. bipunctata* on Ad for three generations, the diet needs further development, since in each generation all the rearing criteria are worse than in preceding one.

The adult gain of 80 % in *C. carnea* on the Ad was fairly high, compared with the gain of 90 % on Mp. VANDERZANT (1969) has reported adult gains of 56—65 % on his artificial diet, but 85 % on the eggs of *Sitotroga cerealella* (Olivier). The larval period on his artificial diet was, however, 2—2.5 times that on the eggs. BUTLER & RITCHIE (1970) also reared *C. carnea* on the eggs of *S. cerealella* and followed the development of larvae and pupae. At +25° C larval development took 10.6 days and pupal development 8.8 days, a total of 19.4 days. On the artificial diet of HAGEN & TASSAN (1970) the total at +25° C was 21.9 days. In this study the corresponding totals were 19.0 days on Mp and 23.9 days on the Ad, the retardation was 25.5 %. On many diet modifications some larvae did not spin a puparium. Some of these developed to adults, but usually they did not.

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