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 weight 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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Index words: Adalia bipunctata, artificial diet, Coccinella 7-punctata, Coccinellidae spp., Chrysopa carnea, predatory insect.

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 (DeGeer) 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 which 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.

<table>
<thead>
<tr>
<th>Larval-adult diets</th>
<th>Mp-Mp</th>
<th>Ad-Mp</th>
<th>Mp-Ad</th>
<th>Ad-Ad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of 1 instar larvae in expt</td>
<td>80</td>
<td>120</td>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

- Adult emergence %
  - Mp-Mp: 95
  - Ad-Mp: 76.7
  - Mp-Ad: 93
  - Ad-Ad: 75.5

- Survival % at start of egg-laying
  - Mp-Mp: 91.3
  - Ad-Mp: 80.8
  - Mp-Ad: 85
  - Ad-Ad: 67.5

- Sex ratio (♀♀ %) at emergence
  - Mp-Mp: 60.5
  - Ad-Mp: 60.9
  - Mp-Ad: 57.0
  - Ad-Ad: 62.9

- % of fertile ♀♀ in total of ♀♀ emerged
  - Mp-Mp: 89.1
  - Ad-Mp: 80.4
  - Mp-Ad: 58.5
  - Ad-Ad: 49.5

- Hatching potential of eggs as %
  - Mp-Mp: 74.2
  - Ad-Mp: 61.8
  - Mp-Ad: 33.4
  - Ad-Ad: 30.6

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). 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 *Coloradlo rusomaculata* (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.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of larvae tested and adults obtained larvae adults %</th>
<th>Developmental period in days</th>
<th>Adult wt at emergence in mg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>larval</td>
<td>pupal</td>
</tr>
<tr>
<td><em>Adalia bipunctata</em></td>
<td>Ad 320 243 75.9</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Mp 180 169 93.9</td>
<td>—</td>
<td>—</td>
</tr>
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<td></td>
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<td>—</td>
</tr>
<tr>
<td><em>Coccinella 7-punctata</em></td>
<td>Ad 139 46 33.1</td>
<td>24.0±0.4</td>
<td>4.2 ±0.1</td>
</tr>
<tr>
<td></td>
<td>Mp 20 18 90.0</td>
<td>11.3±0.4</td>
<td>4.2 ±0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>280.6***</td>
<td>0.63NS</td>
</tr>
<tr>
<td><em>C. transversoguttata</em></td>
<td>Ad 12 4 33.3</td>
<td>32.2±1.3</td>
<td>5.7 ±0.3</td>
</tr>
<tr>
<td></td>
<td>Mp 10 8 80.0</td>
<td>14.3±0.4</td>
<td>5.6 ±0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>134.5***</td>
<td>0.16NS</td>
</tr>
<tr>
<td><em>Hippodamia 13-punctata</em></td>
<td>Ad 42 27 66.7</td>
<td>20.5±0.6</td>
<td>4.7 ±0.1</td>
</tr>
<tr>
<td></td>
<td>Mp — — —</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><em>Propylaea 14-punctata</em></td>
<td>Ad 32 27 84.4</td>
<td>12.4±0.3</td>
<td>2.8 ±0.1</td>
</tr>
<tr>
<td></td>
<td>Mp — — —</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><em>Chrysopa carneae</em></td>
<td>Ad 25 20 80.0</td>
<td>15.1±0.4</td>
<td>8.8 ±0.3</td>
</tr>
<tr>
<td></td>
<td>Mp 10 9 90.0</td>
<td>10.7±0.4</td>
<td>8.3 ±0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42.3***</td>
<td>0.56NS</td>
</tr>
</tbody>
</table>

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 postovisitoting 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).
**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.

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

*H. 13-punctata* and *P. 14-punctata* were not reared on aphids at all, but the adult emergence percentages on the Ad were promising 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 %n. 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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